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OMATON DIVISION

BURNDY
Corporation
NORWALK, CONNECT.

TEL. TEMPL
TWX NO 203
CABLE: BURN

for ager

10 May 1963

TO WHOM IT MAY CONCERN

We have found an error on the cover page of the Final Report dated 18 February 1963, on "Flat Flexible Cable Connector" by the BURNDY Corporation, Norwalk, Conn.

We are enclosing replacement copies of this page and request that you insert them in the report books that you have already received.

We are sorry for any inconvenience this may have caused.

Sincerely,

BURNDY CORPORATION

Robert G Knowles

Robert Knowles
Design Engineer
Connector Development
OMATON DIVISION

RK:mjd

(4) 6.60 (5) 153900 (7)+(8) NA

(9)

FINAL [redacted]

RESEARCH, DESIGN & DEVELOPMENT

(15) CONTRACT [redacted] DA-36-039 SC87274

(6) FLAT FLEXIBLE CABLE

CONNECTOR.

(11) 18 FEB[redacted]63 (12) 55p. (13) NA

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File No. .... 40596-PM-61-93-91 (20) U

PR & C No. .... 61-ELP/D-4404R (21) NA

Tech. Req'ment No. .. SCL-7583

fd

(10)

Prepared By:

Robert G. Knowles
Design Engineer

Glenn M. Osborn, Supv.
Basic Dev. Unit "A"
OMATON DIVISION

#1- AD-263051
#2- AD-270579

BURNDY CORPORATION
NORWALK, CONNECTICUT

FINAL REPORT
RESEARCH, DESIGN & DEVELOPMENT
CONTRACT NO: DA-36-039 SC90721

FLAT FLEXIBLE CABLE CONNECTOR

18 FEBRUARY 1963

File No. 40596-PM-61-93-91

PR & C No. 61-ELP/D-4404R

Tech. Req'ment No. .. SCL-7583

Prepared By: Robert G. Knowles

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Glenn M. Osborn

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Basic Dev. Unit "A"
OMATON DIVISION

BURNDY CORPORATION
NORWALK, CONNECTICUT

TABLE OF CONTENTS

PURPOSE

The purpose of this contract is the development of a better type of Flat Flexible Cable connector. Present installation methods for this cable are unsatisfactory because of the difficulty in preparing the cable for installation. The reliability of the present connectors under shock, vibration and environmental conditions leaves much to be desired.

The difficulty in terminating Flat Flexible Cable has been the major deterrent to its general use. The weight and space saving characteristics of this type of cable would make it ideal for many military applications once the installation and termination problems have been solved.

Presently, there are two accepted methods of terminating Flat Flexible Cable. Both methods require prestripping the conductors on one side and then either soldering or making mechanical connection to it.

Prestripping of the cable insulation is the removal of the insulation from the copper conductors leaving the copper conductors bare. This is accomplished through the use of a prestripping machine. This machine is basically an abrasion machine or grinding wheel. This abrasion wheel is preset to a specific position determined by the insulation thickness of the Flat Flexible Cable being stripped. The cable is then placed into the machine and the insulation removed. Extreme accuracy is required in this machine to properly remove the insulation. Conductor thicknesses range from .0015 to .004. If the tolerances accumulate to either extreme on the conductor and insulation thickness, either of the following cases may exist:

A) Incomplete removal of the insulation resulting in discontinuity in the circuit.

B) Abrading or wearing away of the conductor or, in some cases, the breaking of the conductor strand itself.

Other effects encountered with the use of such a device are as follows:

1) Conductors after prestripping of the insulation form an oxide coat due to the heat generated by removal of the insulation, and due to exposure to the atmosphere.

2) Plating of conductors may be necessary to insure against corrosion.

3) Some types of Flat Flexible Cable are manufactured with a non-conductive black oxide coating. The coating cannot be removed without damaging the conductor to some extent.

4) The use of these prestripping tools require skill and close inspection in order to obtain any degree of reliability.

5) The expense of obtaining and maintaining this stripping machine almost precludes reliable field repairs.

Soldered connections to Flexible Cable have not as yet attained the degree of reliability reached by printed circuits and round wire normally used in electronics work. This is due to the following factors:

1) This very fine conductor foil is very subject to damage unless it is supported or protected by the thermoplastic insulating material.

2) Unless properly stripped, the mylar insulating material will carbonize due to the heat of the soldering iron, thereby affecting the dielectric properties of the insulating material.

The need for a connector which would eliminate the above danger areas is obvious. The intent of this contract was to do the research and development on a connector which is capable of overcoming these shortcomings. The contract also covered the building and testing of samples as well as the submission of samples for functional tests in order to establish the reliability of this type of connection.

ABSTRACT

This contract was presented to a connector manufacturer in order to promote the development of better methods of terminating Flat Flexible Cable, and inspiring original approaches to simplify its installation.

The primary requirements for the new type connector were that the connector be capable of being installed in the field with a minimum of tooling; and, that it provide a highly reliable environmentally sealed connector.

Secondary requirements were that the connector mate with, or be adaptable to, the ultraminiature printed circuit connectors; that it be suitable for rack and panel applications, and that it be fitted with or be capable of being fitted with latches to permit its use as an unmounted disconnect.

~~This report summarizes~~ the various changes from the original concept, and the reasons for them; the research work on the insulation piercing concept; and, a brief analysis of the results of the tests.

The primary problems included:

1) Availability of molding ~~materials~~ capable of withstanding the mechanical requirements of this connector and yet be capable of being molded in the thin sections and around intricate cores.

2) Insufficiently close tolerances on the Flat Flexible Cable.

3) Designing a connector capable of permitting flexibility of application without sacrificing either simplicity of installation or reliability.

The connector which resulted from this contract provided the groundwork for further development and proved the feasibility of the design concept.

PUBLICATIONS, REPORTS, & CONFERENCES

PUBLICATIONS

A) None

REPORTS

A) Quarterly, covering periods:

1) 1 April 1961 to July 1961

2) 1 July 1961 to 1 October 1961

3) 1 October 1961 to 1 February 1962

B) Monthly, covering periods:

1 April 1961 through 1 February 1963

CONFERENCES

I. At Fort Monmouth, N.J., on 18 April 1961

Present:

for BURNDY	for Signal Corps
Mr. LeRoy Gray	Mr. Jack Spergel
Mr. Leonard Grandel	Mr. Elmer Godwin
Mr. Eugene Oshva	Mr. Gerard Reilly
Mr. Wm. Fitzgerald	
Mr. Howard Balshukat	

Subjects discussed:

The Signal Corps' personnel reviewed certain paragraphs in the contract with the BURNDY representatives.

The Signal Corps' personnel reviewed the types of connectors they desired, namely:

1) Rack and panel mounted plug and receptacle type connectors terminated both ends with flat flexible cable.

2) Plug and receptacle type connector terminated one end with flat flexible cable and the other end with Ultra-Miniature Printed Board Connector per Signal Corps' Technical Requirements #SCL6250.

3) Plug and receptacle type connector terminated both ends with flat flexible cable.

The Signal Corps also requested that:

A) The flat flexible cable enter vertically as well as horizontally into the connector. The only stipulation is that the bending of the conductor take place within the connector.

B) The dead end of the cable should be retained within the connector.

C) Adaptors may be used in conjuction with these connectors. This possibility should be kept in mind in the design of the connectors.

D) A Hermetic sealed bulkhead adaptor may be required in the future.

II. At Fort Monmouth, N. J., on 18 May 1961

Present:

for BURNDY	for Signal Corps
Mr. Wm. Fitzgerald	Mr. Jack Spergel
Mr. Eugene Oshva	Mr. Elmer Godwin
	Mr. Gerard Reilly

Discussion:

The discussion held was a review of the final design concept. Certain modifications were suggested by the Signal Corps at that time. These modifications were as follows:

A) Guiding the flexible cable into the piercing area of the connector may be accomplished through the use of molded guide slots. The slots may be used for straight and right angle entry of the flexible cable and the wedge design and piercing elements may be used as a strain relief if our investigation proves satisfactory.

B) Signal Corps personnel would prefer a hermaphrodite contact design for mating with rack and panel and printed circuit board connectors if possible. The design, however, was left to our discretion, with the understanding that

the proposed contact design would not be sacrificed because of the need to mate with printed circuit board connectors, and that emphasis would be given to contact strength.

C) Signal Corps' personnel prefer the use of a shell for guiding of the rack and panel type connectors. The shell may be made of metal or may be an integral part of the plastic body design.

General approval was given to the approach and a working sample which was previously made for demonstration purposes showed the feasibility and advantage of terminating the flat flexible cable in this manner.

III. At BURNDY Corporation, Norwalk, Conn. on 21 July 1961.

Present:

<u>for BURNDY</u>	<u>for Signal Corps</u>
Mr. Glenn Osborn	Mr. Jack Spergel
Mr. Eugene Oshva	Mr. Gerard Reilly
Mr. Leonard Grandel	
Mr. Wm. Fitzgerald	

Subjects discussed:

The Signal Corps questioned the method of strain relieving the cable from external forces. BURNDY showed the feasibility of using the existing pressure bar as the strain relief. This method will further be evaluated upon completion and receipt of the experimental parts.

Alignment of the cable (conductors) with the insulation piercing elements was also discussed. It was brought to the attention of the Signal Corps that the alignment was transferred from the pressure bar to the contact body, thus reducing the accumulation of tolerances for indexing.

Sealing of the connector was discussed. The initial intention was to have the connector sealed after complete installation had occurred (cable installed and the plug mated with the receptacle). The Signal Corps, however, desired a connector which was sealed before the complete installation had occurred, i.e., the male and female connector halves must be completely sealed before engagement of one with the other.

The Signal Corps was notified that a revision of this nature would necessarily mean modification or complete revision of the present production detail drawings. The Signal Corps in turn indicated that the sealing requirement, as defined by them, was necessary.

Retention of the dead end of the cable was discussed. At that time no suitable means of accomplishing this task had been presented. The Signal Corps was assured that the final design would include this feature.

The contact (pin and socket) end of the insulation piercing element was also discussed. It was brought to the attention of the Signal Corps that the present mating tolerance specification of plus or minus 1/16 would not insure connection with the printed circuit board connector. It was mutually agreed that the printed circuit board connector would have to be mounted flush with the TAPECON connector to insure connection. It was also agreed that the contact end of the insulation piercing contact elements would be of the closed entry type.

IV. At Fort Monmouth, N.J., on 17 October 1961

Present:

for BURNDY	for Signal Corps
Mr. LeRoy Gray	Mr. Jack Spergel
Mr. Glenn Osborn	Mr. Elmer Godwin
Mr. Eugene Oshva	Mr. Gerard Reilly
Mr. Howard Balshukat	

Subjects discussed:

The detail drawings were reviewed with the Signal Corps. The function of the wedge was described in conjunction with the contact body and the method of cable indexing with the insulation piercing elements (contacts) were reviewed.

The resilient pressure pad and the straight tooth approach in conjunction with one another were discussed as to the reason for this selection. The reasoning was explained to the satisfaction of the Signal Corps.

The Signal Corps emphasized the importance of reliability data electrically, and mechanically. BURNDY assured the Signal Corps that such an investigation is uppermost in their plans.

The primary concern lies in the fact that the termination is not visible to the eye and no means, except electrical testing, can show that continuity has been achieved.

<u>Specifically</u>: The tests will be run at maximum and minimum tolerance conditions on the wedge angle (pressure bar) and mating angle (contact body).

The maximum and minimum conditions of indexing the cable with the piercing contacts (i.e., alignment of conductors with the piercing contacts).

The maximum and minimum conditions of tooth height.

The Signal Corps inquired as to the effect of conductor width vs. that of indexing. Due to the present specification on conductor width, tolerances must be held very closely on the connector. It was suggested that the Signal Corps include in their specification the conductor width of .030". If this could be included, the indexing of the cable would not be as critical and the reliability of indexing would be increased. It was agreed that this matter would be reviewed by the Signal Corps and we would be notified as to its acceptance or rejection.

The Signal Corps reminded us that two types of samples may be submitted, i.e., contact variations may be submitted for evaluation, if it was felt that their evaluation of these contact variations proved to be equally effective or that certain features were contained in the variations which could not be combined. It was agreed that this would be done if the situation presented itself.

The Signal Corps asked that we investigate various means of accomplishing a 90° take-off of the cable from the connector. Various methods were discussed and our present method was reviewed.

The Signal Corps inquired as to the locking device which would hold the connector halves together in the free state. At present, we do not have such a device incorporated, but will in the future. The Signal Corps agreed that for experimental models this would not have to be incorporated, but should be shown on the drawings.

The use of a metal shell around our connector was discussed. It was agreed that a connector of this size would not be exposed to large shock in a rack and panel application. Therefore, a metal shell will not be required.

Due to the various delays in the contract dates, it was agreed that the following dates will be our objective:

Experimental models with complete test evaluation - March '62

Final development models with complete test evaluation - July '62 (dependent on 4 week Signal Corps' approval on experimental models).

Contract completion - August '62 (dependent on 4 week Signal Corps approval on final development models).

The detail production drawings were approved by the Signal Corps with no change in design.

V. At Fort Monmouth, N.J., on 5 April 1962

Present:

for BURNDY	for Signal Corps
Mr. Eugene Valehrach	Mr. Jack Spergel
Mr. Glenn Osborn	Mr. Elmer Godwin
Mr. Eugene Oshva	Mr. Gerard Reilly

Subjects discussed:

The paragraphs related to shells and latching devices were discussed and clarified. It was agreed that samples per item 4, paragraph 'C', would not be included with the experimental models, but would of course be supplied in the final submission of the development models.

The Signal Corps requested that we consider modifications that would reduce the size of the TAPECON.

The Performance Test schedule was reviewed in detail. Several changes were requested by the Signal Corps. It was agreed that these changes would be made and the corrected schedule would be forwarded the following week.

VI. At Fort Monmouth, N.J., on 17 August 1962

Present:

for BURNDY	for Signal Corps
Mr. Eugene Valehrach	Mr. Jack Spergel
Mr. Glenn Osborn	Mr. Elmer Godwin
Mr. Eugene Oshva	Mr. Gerard Reilly

Subjects discussed:

The Performance Test data was discussed and analyzed in detail.

It was agreed that the cable tested had not met the high temperature requirements specified by the manufacturer. The manufacturer confirmed these findings, but felt that it was caused by defective mylar tape rather than any defect in the adhesive or fabrication techniques.

Samples of the cable would be returned to the vendor for a more complete analysis.

We agreed to investigate the feasibility of incorporating the following features in the present design:

1) Polarization of the wedge.

2) A flange to permit pressure sealing to a bulkhead.

3) Reduction of the size of the connector.

We also agreed to run a preliminary investigation to determine whether it was possible to use the insulation piercing concept with flexible, etched printed circuitry.

VII. At the BURNDY Corporation, Norwalk, Conn., on 15 November 1962

Present:

for BURNDY	for Signal Corps
Mr. Glenn Osborn	Mr. Jack Spergel
Mr. Robert Knowles	Mr. Elmer Godwin
Mr. Burt Eden	Mr. Gerard Reilly

Subjects discussed:

1) We confirmed that the submittal of development models would include 24 samples with locking devices per paragraph 'C', item 4 in the Statement of Work.

2) We requested that these connectors be tested in accordance with Group II only of MIL-STD-446. This request was made because both the cable and the connector were approaching their failure point.

   If these connectors were to become production items this problem could be resolved by adding a rib to the back of the wedge or changing the material, however, both of these alternatives would require mold changes.

   Since our experience with the type "P" insulation and the Kel-F insulation indicates that their characteristics are questionable above 100°C we feel that an expensive mold change is not warranted.

3) We agreed to check further into the carbon tracking problem to confirm the nature of the problem and to determine whether or not the problem has been resolved.

4) The Signal Corps requested that the wedge screws be captivated in some way to prevent their being dropped or lost during handling. It was felt that this could be accomplished in time for the submission of the development models.

5) We discussed the desirability of incorporating a dust flange on the body of the connector as well as a means of polarizing the wedges, however, it was agreed that

since these two modifications require changes in the molds and the components for final submission have either been run or scheduled, we would not incorporate these changes in the final development models but we would make the changes on the drawings. These features will be included on the design of connectors under DA36-039 SC90721.

6) We have done preliminary evaluations on the use of these connectors on etched cable. The results indicated that there would be little problem in accommodating etched cable with the insulation piercing approach.

7) We agreed to estimate the labor cost involved in assembling these connectors so we might evaluate the savings which might be realized by the Signal Corps through a reduction in the number of development models submitted.

8) It was also agreed that we would forward to the Signal Corps additional test data related to the experimental models which had been submitted.

VIII. At Fort Monmouth, N. J., on 8 January 1963

Present:

for BURNDY	for Signal Corps
Mr. Eugene Valehrach	Mr. Jack Spergel
Mr. Glenn Osborn	Mr. Elmer Godwin
Mr. Nat Williams	Mr. Gerard Reilly

Subjects discussed:

1) The problems encountered with the wiping gasket during pressure cycling in the humidity chamber were discussed, i.e., the reduction of the interference on the wiping gasket to reduce the engagement force proved detrimental during the 106A humidity test.

2) We agreed to up-date and stamp all the manufacturing drawings.

FACTUAL DATA

Tolerances & Variations in the Flat Flexible Cable

At the outset of the project there existed a difficult tolerance problem in the Flat Flexible Cable. According to SCL7583 the conductors were dimensioned in such a way that the contact for the last conductor, unless it had some thickness, could fall either on the right or the left of a .020 conductor. This incorporates the extreme tolerance variation in the cable only and allows no tolerance for either the location of the cable within the connector or the location of the contacts within the connector body which, of course, is unrealistic.

The manufacture of Flat Flexible Cable is still new and the techniques are constantly being refined as the need to hold tighter tolerances and more stringent requirements appear.

In reviewing this problem with Flat Flexible Cable manufacturers, both George Metter of I.R.C. and Bill Richter of Tape Cable Corp. agreed that they could and would hold the total tolerance accumulation from index edge to last conductor to ± .005 instead of the previous ± .010. To get these closer tolerances we do have to pay a token charge to offset the additional inspection.

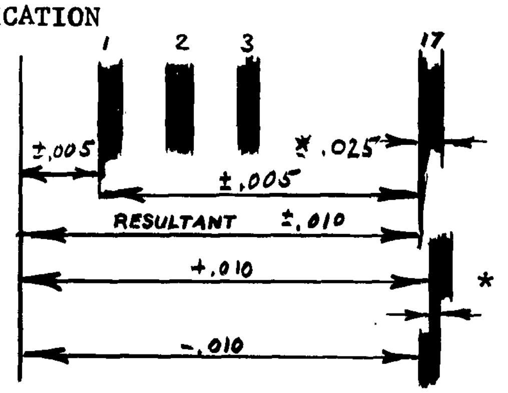
Since the inception of this project a great deal of work has been done by the Institute of Printed Circuits to refine and standardize the dimensioning and requirements of Flat Flexible Cable.

Figure 1

TOLERANCE CONDITIONS

STANDARD CABLE SPECIFICATION

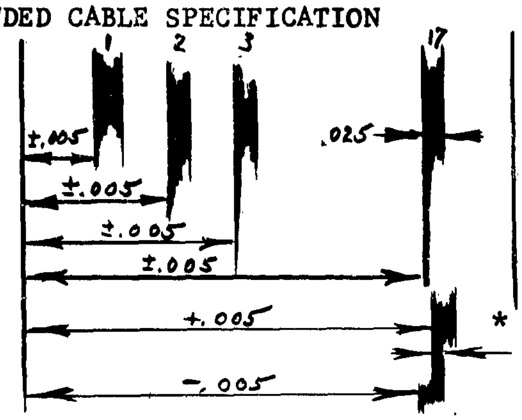
Locating edge on connector



Extreme tolerance conditions. Effective conductor width =.005

Note: *The effective width is further reduced due to tolerance existing on the conductor width.

BURNDY RECOMMENDED CABLE SPECIFICATION



Locating edge on connector

Extreme tolerance conditions. Effective conductor width = .005 *

Note: *The effective width is further reduced due to tolerance existing on the conductor width.

PHASE I: Refinement of the Design Approach
Part I

The initial design and development for this type termination was submitted to Fort Monmouth as the proposed method of terminating Flat Flexible Cable.

As will be disclosed later in this report, many of these features have been improved by further design and development effort. All changes are based on further detailed analysis of the problems and, in most cases, on test information. Documented test data, other than millivolt drop tests, does not exist to date because the majority of testing has been evaluated visually.

The features which this design incorporated at the time were as follows:

1) Design of Cable Terminating Method
(Ref. See Dwg. SKM 10161)

A unique but simple method of obtaining electrical contact between the cable conductors and the "connector contact elements" is the basic principle of BURNDY'S cable terminating connector.

Through the utilization of an insulation-piercing contact element, electrical contact is achieved directly to the cable, completely removing the need for prestripped cable. Thus, the problems and cost inherent in prestripping the cable are eliminated.

In order to conform to the .050 inch conductor spacing, the contacts were staggered in the upper and lower connector halves, and connection was alternately made to the two sides of the cable. (See Figure 2.)

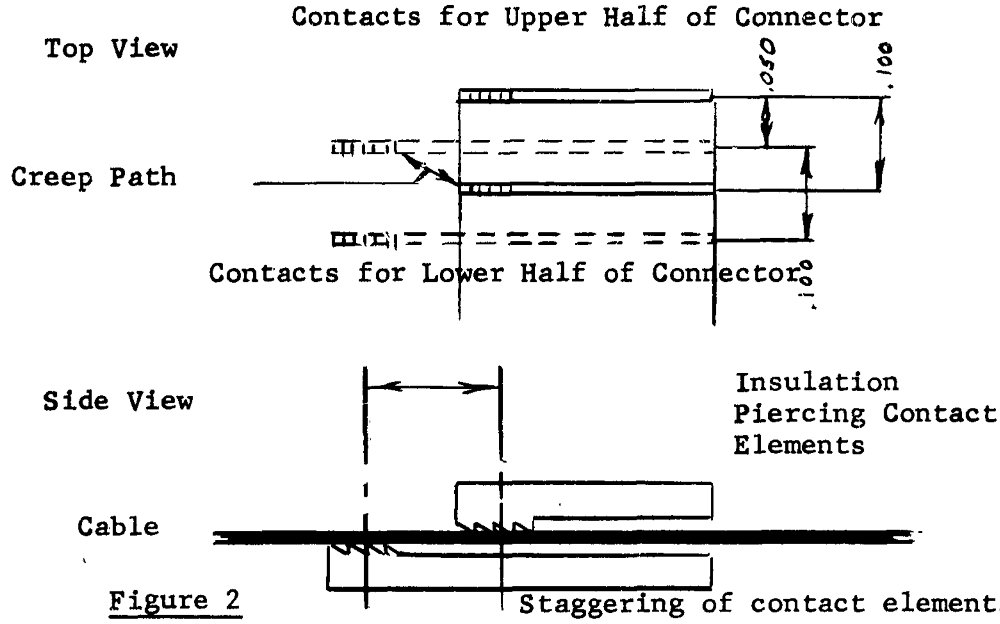


Figure 2

In addition, contact elements were staggered longitudinally on the cable in order to obtain the necessary .060 inch "creep" path to conform to the 600 volts R.M.S. operating voltage. (See Figure 2.) Ref. Para. 3.2.1.2 of SCL7583.

2) Installation of Cable
(Ref. See Dwg. SKM10161)

The cable was introduced into the connector through a slot at the rear of the tapered shell and fed between the connector halves. The cable was then aligned by seating the prepunched cable on alignment pins. (See Figure 3.)

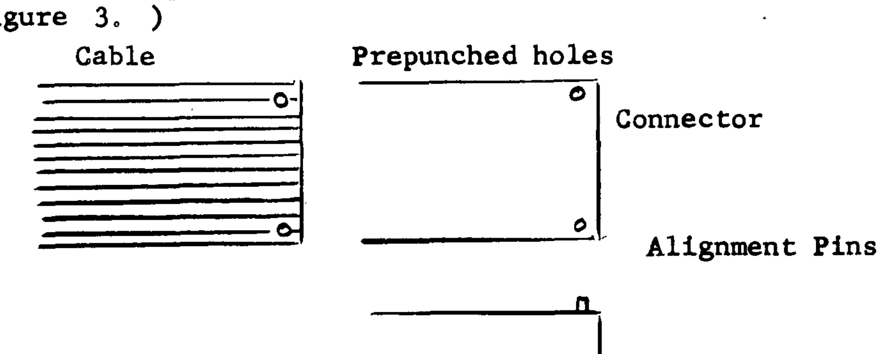


Figure 3

To achieve contact, the jackscrews were tightened. This had the effect of forcing the connector halves into the shell and through camming action between the shell taper and the taper on the connector halves, they are forced together.

The contact elements would then exert pressure in opposition to each other, thus preventing any possible slip of the cable, also achieving a sliding wipe action between the contact and the conductor. (See Figure 4 .)

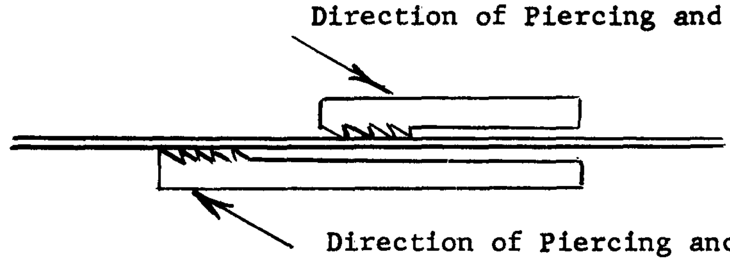


Figure 4

After contact to the cable is completed, an external cable clamp is tightened to provide strain relief to external forces applied on the cable.

3) Design of Piercing Element

It was felt that the "tooth" or "piercing" height of the contact element should vary with respect to the thickness of insulation on various cables in order to obtain a reliable connection on all cables. To compensate for this and for additional tolerance conditions, the staggered "tooth height" approach was developed. (See Figure 5.)

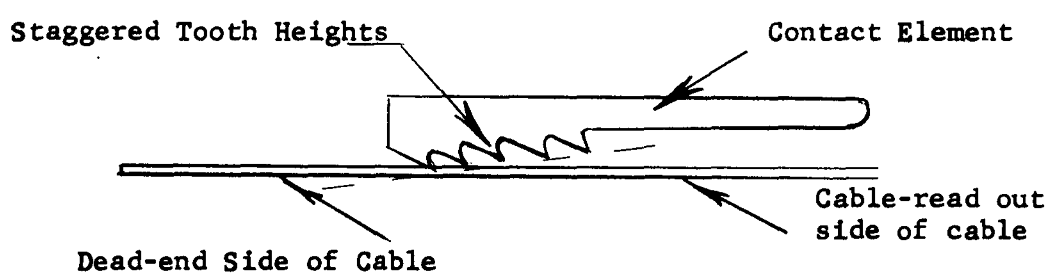


Figure 5

This approach insures contact between piercing element and cable conductor. The tooth height is greatest at the 'dead end' side of the cable and get progressively smaller towards the 'read-out' side of the cable. This will insure continuity in the circuit if piercing of the cable conductor should occur.

4) Contact Tabs
(Ref. See Dwg. SKM10161)

Hermaphordite contact tabs were designed for interchangeability of contacts, decreased costs, and to permit the molding in of the contact elements.

5) Adaptor
(Ref. See Dwg. SKM10162)

Interconnection between Flat Flexible Cable and "Ultra-Miniature Printed Circuit Connector" was to be achieved through the use of an adaptor device. This adaptor contains its own contacts which gave the connector the flexibility of mating with the "Ultra-Miniature Printed Circuit Connector".

6) Cable Strain Relief

This relieves the cable of external forces which may be applied and prevents transmission to the piercing contact elements.

PHASE I: Evaluation of Design Approach
Part 2

A) Evaluation of Cable Termination Method

After careful analysis of many concepts, the insulation piercing type connector was selected. The benefits derived in making a termination in this manner are as follows:

1) No expensive stripping tool necessary.
2) Conductors are not exposed to the atmosphere before installation.
3) Plating of exposed conductors is not necessary for protection against corrosion.

4) Highly skilled technicians are not required.
5) A more positive connection is made between cable conductor and contacting element.
6) No damage can occur or repairs necessary to the cable previous to installation.
7) Soldering of connections eliminated.
8) Overall cost of installation very low.

It was felt that the staggered location of the contacts (Ref: Figure 5 side view) increases the length of the connector. Also, having two halves to each connector body (Dwg. SKM10161) increases the height of the connector. The resolution of this problem increasing the volumetric efficiency of this connector is described later in this report.

B) Installation of Cable

The cable installation described, was felt to be complex and dependent on many variables. These variables include such things as tolerance accumulation between location of prepunched holes in cable and alignment pins in the connector, additional operations necessary in prepunching cable, etc. This report will disclose a more satisfactory means of accomplishing the same end.

C) Design of Piercing Contact Elements

It was felt that the effectiveness and reliability of the piercing contacts could be increased by having an increased number of piercing teeth per contact. This phase will be examined more fully.

D) Contact Tabs

The hermaphordite contact tab approach might be inadequate due to possible electrical intermittency under vibration and shock conditions. A more reliable contact tab or pin and socket will be developed to mate with the Ultra-Miniature Printed Circuit Connector.

E) Adaptor

A pressurized adaptor was included in the original proposal, but with the design modifications incorporated in the final design it became unnecessary and was therefore eliminated by mutual consent.

PHASE I: Development of Final Design
Part 3

In order to avoid some of the complexities of the proposed concept, a simpler design was developed which seemingly accomplished the same end with fewer moving parts and fewer apparent problem areas than the original concept.

Old Concept | New Concept

Figure 6

Though the new design employs the same basic principle as that in the original concept, it permits a decrease not only in the length but in the height as well. With the new design it was possible to incorporate new innovations which provide more exact yet simpler methods of aligning the cable with the insulation piercing elements.

A) Design of the Insulation Piercing Elements

Of course the heart of the connector and the subject of much of the basic design work was the insulation piercing elements. Particularly in the early stages of the design and development of this connector, there was a great deal of controversy over the reliability of this type of connection. Though some work had been done during the early concept stages of the design, no valid reliability data had yet been accumulated. The small amount of testing that had been done had been exploratory in nature rather than the stage-by-stage systematic and well controlled testing required for design evaluation.

It was, therefore, decided to set up a series of tests and parameters which would provide an empirical background for our design work. An adjustable fixture would then be built to simulate a connector under the established conditions.

PHASE II: Establishing a Test Program, Parameters and A Test Fixture

A) Variables to be tested:

1) Effect of insulation piercing contact thickness.
2) Optimum wedge angle.
3) Tooth height.
4) Tooth configuration.
5) Type of pressure bar (wedge).
6) Insulations accommodated.
7) Tooth wear.
8) Plating.

B) Parameters to be tested:

1) Force required to drive the wedge into the teeth and establish contact.
2) Millivolt drop from the conductor to the contact.
3) Conductor damage caused by overpenetration of the insulation piercing element.

C) Design of a testing fixture:

A fixture had to be designed which would be capable of testing all of the above variables for the parameters described to the extent outlined below:

1) The test fixture had to be capable of accommodating contacts up to .020 thick.
2) The wedge angle had to be capable of being varied from 25° to 50°.
3) The amount of exposed tooth was varied by grinding off varying amounts from the back of the contacts.
4) Various types of pressure bars were tested by substitution.

See SKM10826 in the APPENDIX.

Laboratory Test Data Comparing the Effect of the Number of Insulation Piercing Elements (Teeth) Vs. Millivolt Loss

A machined sample of the TAPECON connector has been made in the Norwalk Sample Shop. Exact conformance to dimensional requirements was not achieved because of modular construction necessary with a machined part. Therefore, the sample was not representative of the assembly that is expected from properly molded components. However, this sample did prove quite useful.

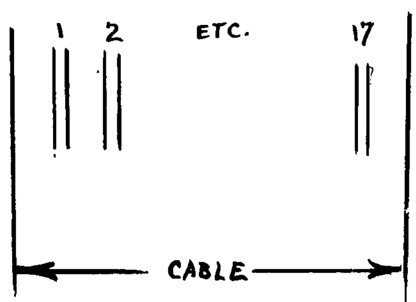
Using this test fixture described in the first Quarterly Report, the effect of the number of piercing elements per conductor vs. millivolt loss was determined as follows:

TEST DATA:

Conditions: Number of teeth (piercing elements) - 4
Arrangement - straight
Protrusion - .015
Test Current - 1 Amp
Readout - On odd side

Results: Millivolt drop

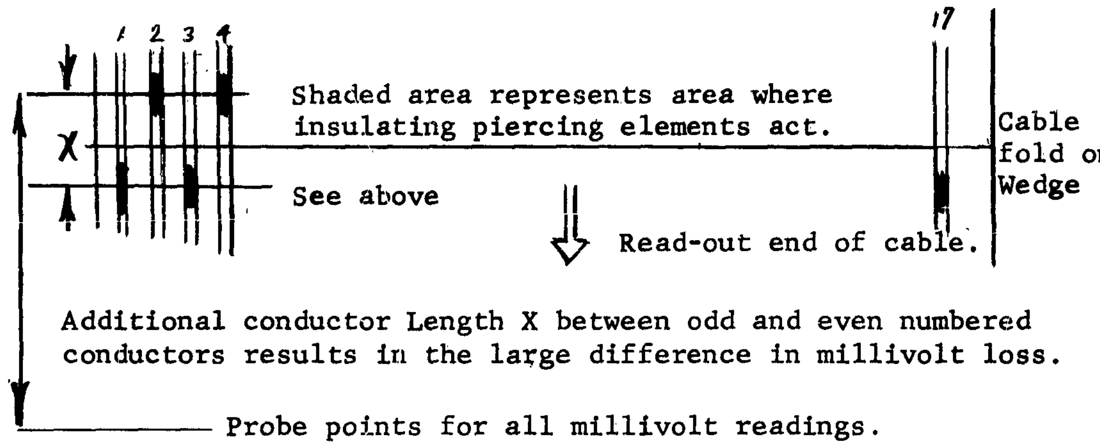
1) 6.8 mv	9) 8.5
2) 11.1	10) 12.2
3) 7.1	11) 8.2
4) 10.8	12) 10.0
5) 7.0	13) 7.5
6) 11.2	14) 10.2
7) 7.0	15) 7.2
8) 10.6	16) 10.8
	17) 8.0



Since the insulation piercing contact elements were staggered, two rows of insulation piercing connections were made as shown in the Figure on the following page.

INTERPRETATION OF RESULTS

Cable



Since the odd numbered conductors are slightly closer to the readout end of the cable, the millivolt results now read as follows:

1) 6.8 mv	2) 11.1
3) 7.1	4) 10.8
5) 7	6) 11.2
7) 7	8) 10.6
9) 8.5	10) 12.2
11) 8.2	12) 10.0
13) 7.5	14) 10.2
15) 7.2	16) 10.8
17) 8.0	

average MVD of odd conductors = 7.49

Variation of MVD for above = -.7 & + 1 or ± 1 mv

average MVD of even conductors = 10.86

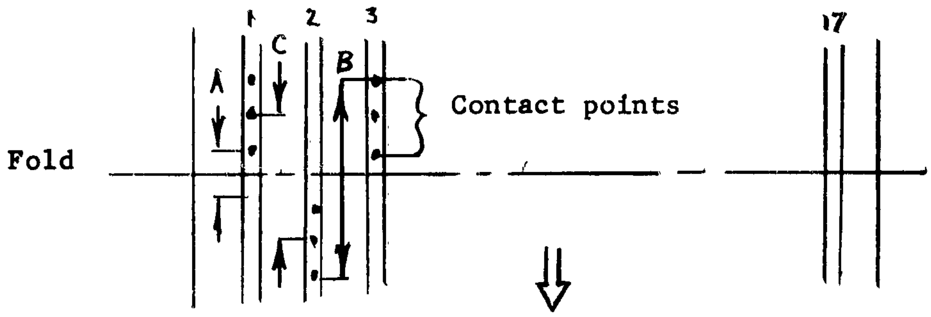
variation of MVD for above = -.86 & +1.34

average MVD for cable = 9.07

variation for above = -2.27 + 3.13

From the above results, we find ourselves with an approximate maximum millivolt drop variation of 5.5 mv.

The reason for the above MVD variation is as follows:



Length A = .150
Length B = .400
Millivolt drop per .100 inches on conductor = 1.3 mv

Millivolt drop across 'A' = 1.95 mv
Millivolt drop across 'B' = 5.2

Assuming 'C' to be the average distance between alternate connections ('C' = .300) the MVD would be approximately 3.9 mv due to the extra conductor length.

Conditions:

Number of teeth (piercing elements) - 3
Arrangement - straight
Protrusion - .015
Test Current - 1 Amp.
Readout - on even side

1)	9.0 mv	9)	9.3
2)	6.6	10)	6.1
3)	11.0	11)	13.0
4)	7.2	12)	6.5
5)	9.5	13)	12.0
6)	7.6	14)	7.6
7)	9.7	15)	12.0
8)	7.4	16)	7.0
		17)	11.0

Segregated results
odd - conductors - even

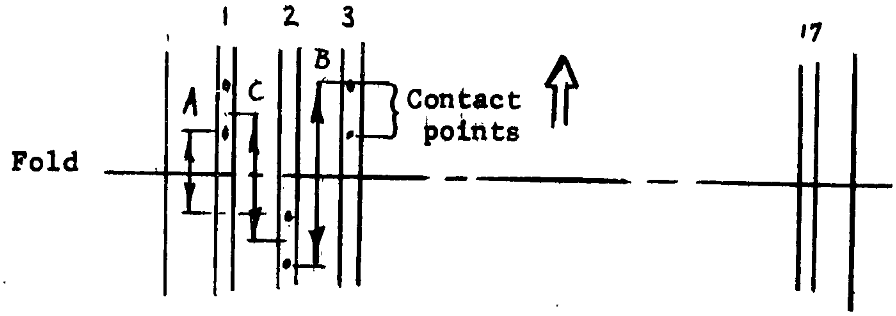
1)	9.0	2)	6.6
3)	11.0	4)	7.2
5)	9.5	6)	7.6
7)	9.7	8)	7.4
9)	9.3	10)	6.1
11)	13.0	12)	6.5
13)	12.0	14)	7.6
15)	12.0	16)	7.0
17)	11.0		

odd average = 10.72
odd variation = -.28 & + 2.28

even average = 7.0
even variation = -.9 & + .6

total average = 8.97
total variation = 1.87 & + 4.03

Max. M.V. variation = 6 M.V.



Length A = .150
Length B = .400
Millivolt drop per .100 inches on conductor = 1.3 mv

Millivolt drop across 'A' = 1.95 mv
Millivolt drop across 'B' = 5.2

Assuming 'C' to be the average distance between alternate connections ('C' = .300) the MVD would be approximately 3.9 mv due to the extra conductor length.

Conditions:

Number of teeth (piercing elements) - 2
Arrangement - straight
Protrusion - .015

Test Current - 1 Amp.
Readout - on <u>odd</u> side

Results - M.V.D.

1)	7.3	10)	11.5
2)	11.0	11)	8.6
3)	6.9	12)	11.5
4)	11.5	13)	7.3
5)	7.0	14)	11.0
6)	12.0	15)	7.1
7)	7.8	16)	11.3
8)	11.0	17)	8.0
9)	7.5		

Segregated
Odd - conductors - Even

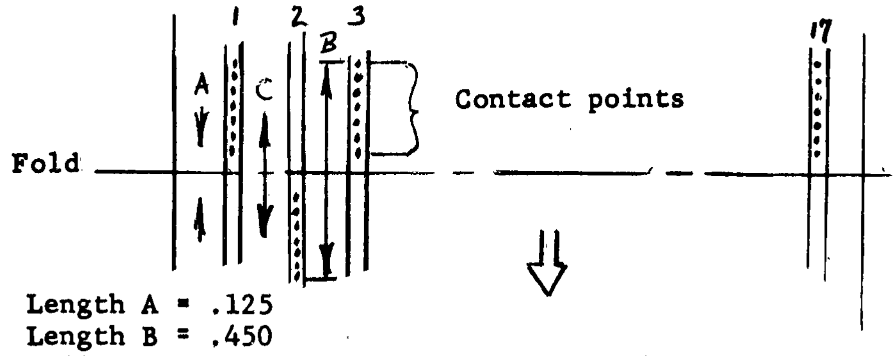
1)	7.3	2)	11.0
3)	6.9	4)	11.5
5)	7.0	6)	12.0
7)	7.8	8)	11.0
9)	7.5	10)	11.5
11)	8.6	12)	11.5
13)	7.3	14)	11.0
15)	7.1	16)	11.3
17)	8.0		

odd average = 11.35
odd variation = -.35 & + .65

even average = 7.50
even variation = -.6 & + 1.1

total average = 9.31
total variation = + 1.69 & - 2.41

Max. M.V. Variation = 4.1 MV



Length A = .125
Length B = .450
Millivolt drop per .100 inches on conductor = 1.3 mv

Millivolt drop across 'A' = 1.62 mv
Millivolt drop across 'B' = 5.85

Assuming 'C' to be the average distance between alternate connections ('C' = .290) the MVD would be approximately 3.8 mv due to the extra conductor length

Conditions:

Number of teeth (piercing elements) - 7
Arrangement - straight Test Current - 1 Amp.
Protrusion - .015 Readout - on <u>even</u> side

Results - M.V.D.

1)	9.1	10)	6.0
2)	6.3	11)	12.3
3)	9.8	12)	6.1
4)	6.3	13)	11.0
5)	9.0	14)	8.0
6)	6.0	15)	10.1
7)	10.3	16)	7.1
8)	6.5	17)	10.5
9)	10.0		

Segregated Results
Odd - conductors - Even

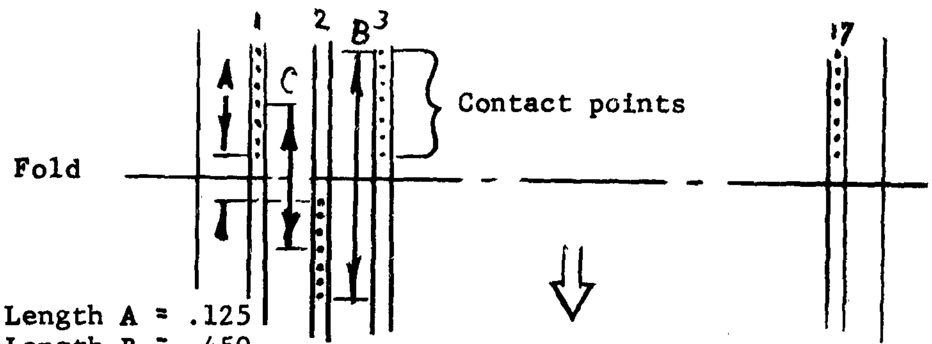
1)	9.1	2)	6.3
3)	9.8	4)	6.3
5)	9.0	6)	6.0
7)	6.0	8)	6.5
9)	6.5	10)	6.0
11)	6.0	12)	6.1
13)	6.1	14)	8.0
15)	8.0	16)	7.1
17)	7.1		

odd average = 7.52
odd variation = -1.52 & + 2.28

even average = 6.53
even variation = -.53 & + 1.47

total average = 7.05
total variation = 0.95 & + 0.95

Max. M.V. variation = 3.8



Length A = .125
Length B = .450
Millivolt drop per .100 inches on conductor = 1.3 mv

Millivolt drop across 'A' = 1.62 mv
Millivolt drop across 'B' = 5.85

Assuming 'C' to be the average distance between alternate connections ('C' = .290) the MVD would be approximately 3.8 mv due to the extra conductor length.

Conditions:

Number of teeth (piercing elements) - 7
Arrangement - curved — Test Current - 1 Amp.
Protrusion - .015 — Readout - on <u>even</u> side

Results - M.V.D.

1)	8.9	10)	6.3
2)	6.5	11)	11.8
3)	9.0	12)	6.2
4)	6.4	13)	11.5
5)	9.2	14)	7.6
6)	5.9	15)	11.7
7)	10.1	16)	6.5
8)	7.0	17)	9.5
9)	9.8		

Segregated
Odd - conductors - Even

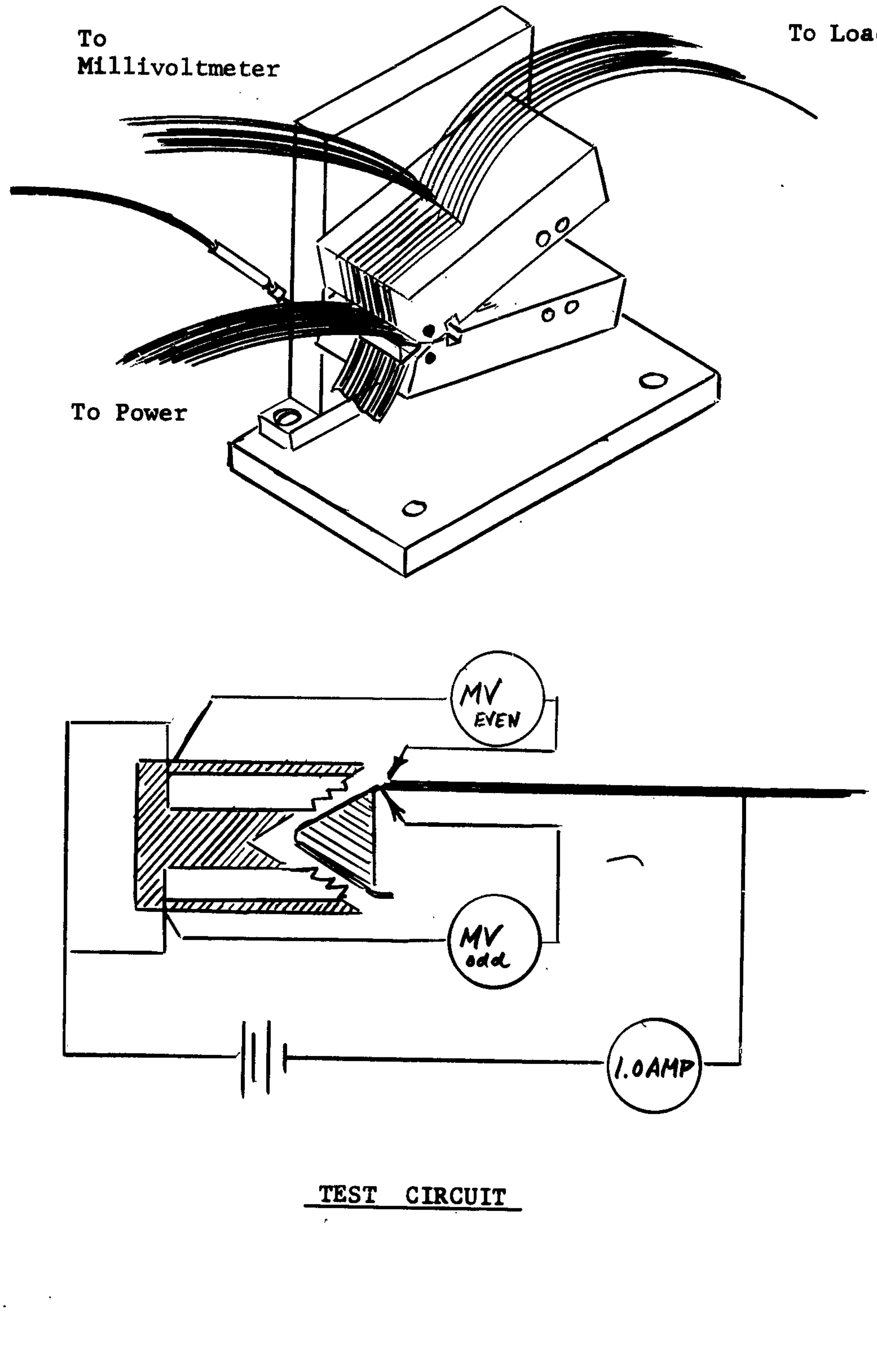
1)	8.9	2)	6.5
3)	9.0	4)	6.4
5)	9.2	6)	5.9
7)	10.1	8)	7.0
9)	9.8	10)	6.3
11)	11.8	12)	6.2
13)	11.5	14)	7.6
15)	11.7	16)	6.5
17)	9.5		

odd average = 10.18
odd variation = -1.28 & + 1.62

even average = 6.55
even variation = - .35 & + 1.05

total average = 8.46
total variation = + 3.34 & - 2.26

Max. M.V. variation = 5.6 MV



TEST CIRCUIT

Because of the close interrelation of all the variables, it was necessary to study the extent of their effect empirically rather than analytically.

The testing was slow and tedious and the results did not show any sharp breaking points as might have been expected, but rather general trends which were subject to interpretation; however, we were able to establish the following conclusions.

CONCLUSIONS DERIVED FROM TESTING

A) BURNDY tests as described show that the wedge angles had a definite effect on the type of termination produced. This effect proved to be as follows:

1) As the wedge angle increased, the insulation piercing elements (teeth) were caused to penetrate the insulation of the cable closer to 90° or perpendicular. This gave concentrated force on the conductors at the points of contact and increased the possibility of puncturing or severing the conductor.

2) As the wedge angle increased, the insulation piercing teeth were caused to penetrate the cable at a smaller angle, thus sliding on the conductor after the insulation piercing had occurred. This gave the desired wiping action and a greater contact area between the conductor and the insulation piercing contact element.

B) Insert thickness ranging from .005" to .020" tested at various angles:

1) The thinner the contact element, the greater the chance of piercing and slicing through the entire cable.

2) The thicker the contact element, the more force required to pierce the insulation leading to the additional force on each conductor which causes rupturing of the conductors.

3) As the wedge angle increased, conditions #1 and #2 above were increased.

4) The twisting tortion effort applied to the wing nuts to effect piercing of the cable reduces as the wedge angle is decreased, i.e., 50° angle requires approx. 10-12 in. lbs. and 25° angle requires approx. 6-8 in. lbs.

5) As the contact element thickness increased beyond .015, the certainty of severing the complete conductor increased.

C) Varying the height of the piercing elements (teeth) from .005 to .020 produced the following conclusions:

1) There was no continuity below .005 protrusion.

2) There was some puncturing of the conductors when .005 thick contacts were allowed to protrude more than .010.

3) With .010 thick contacts there was no lack of continuity, provided the teeth protruded from the supporting face a minimum of .010.

4) With .010 thick contacts there was no puncturing of the conductor, provided the contact teeth did not protrude more than .020.

5) Due to the above conclusions, BURNDY has set the tooth height from .010 to .015.

PHASE III: Application of the Test Data and Engineering Background Gained Through Testing

As can be seen by the typical type results illustrated above, the testing did not provide a sure cure for all of our design problems, but it did confirm our feelings and provide us with additional background on which to base our decisions.

The selection of the tooth angle, wedge angle, number of teeth, etc., became one of engineering judgment rather than one of precise calculations, since many of the conditions which would ultimately be present in the connector could not be simulated in the fixture or fabrication in a MOCK UP.

The decision was made to design for seven (7) teeth .010 thick since it would be easy to reduce the number of teeth

while, if we had designed for two (2) teeth, it would have been a major problem to increase the number.

The straight tooth configuration was used and an included angle of 25^{o} was indicated to be most favorable.

During the early stages of the developmental testing it was discovered that the force required to produce penetration on 17, 7 tooth contacts was excessive for the rest of the connector. The wedge showed excessive bowing, the plug body was showing signs of distortion and the plug body was breaking loose from the hood.

For the above reasons, and because the additional teeth contributed so little as can be seen in the previous test data, we removed alternate teeth in each contact leaving three teeth. In testing these connectors, there seemed to be no significant increase in the millivolt drop and no other detrimental effects. We, therefore, adopted the three teeth and thereby reduced the stress on the wedge and plug body.

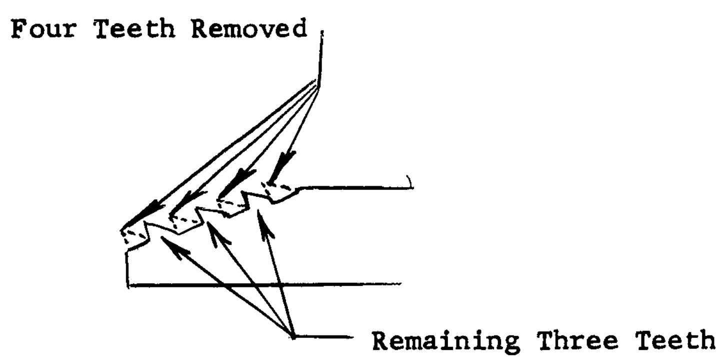


Figure 7

A) Design of the Pressure Bar:

Initially a molded plastic wedge was intended, but during the course of the testing program it was observed that with the plastic wedge the insulation piercing elements would cause pin holes or puncturing of the cable conductors. This was felt to be because of concentrated load between tooth and conductor. In an effort to distribute this concentrated load, the resilient pad was incorporated.

The load previously concentrated was thereby dispersed over a greater area. Previously, the force applied to the conductor by any tooth was reacted to by an equal force of the hard wedge surface. When the tooth acts against the conductor, the force on the conductor is now absorbed by the resilient pad which distributes it to the wedge.

In the application of the pressure bar certain cumulative tolerance conditions (cable thickness, resilient pad thickness and variations in the height of the teeth) could cause variations in the degree to which the cable would be impressed against the insulation piercing elements. The resilient pad on the face of the wedge compensates for this variation in the following manner.

The sketch below illustrates the initial contact of one of the insulation piercing elements with the cable.

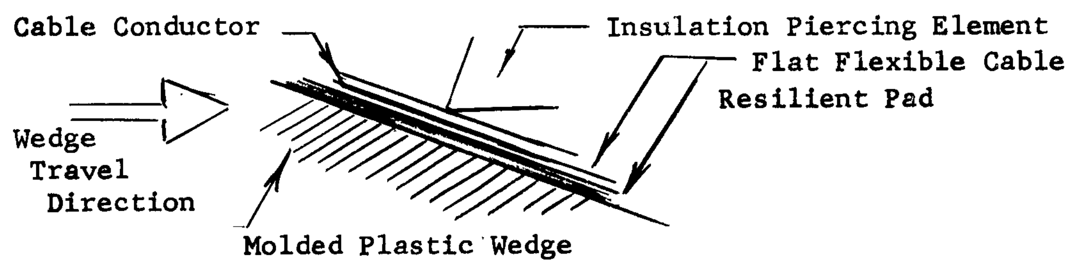
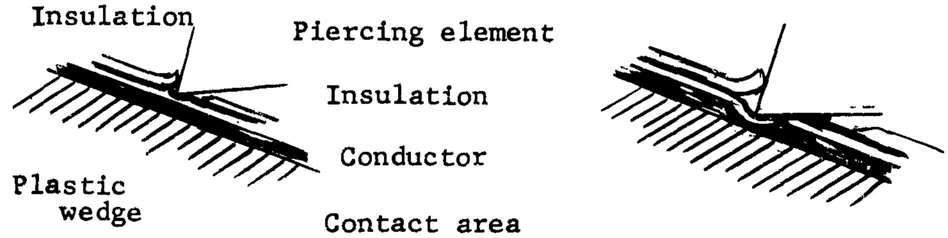


Figure 8

As the wedge travel continues, the piercing element penetrates the insulation and applies its force on the conductor which distributes it to the wedge. As the wedge moves further forward, the distribution forces increase but remain below that required to puncture the conductor. This is illustrated in the sketches below.



Initial Contact — Contact After Wedge Travel

Figure 9

It is most important to note that due to the wedge design the ratio of pressure bar travel to that of insulation piercing depth is 5 to 1, i.e., for a wedge travel of .020 the depth of penetration of the piercing elements is .004. In this manner, tolerance accumulation is compensated for.

Many different types, durometers and thicknesses of elastomers were tested to determine their relative effect on piercing of the insulation, penetration of the conductor, and force required to achieve continuity on all conductors. It was important to select an elastomer with high tear and abrasion resistance, and one which would not be subject to excessive compression set at high or low temperatures. A tabular breakdown of the elastomeric materials tested will be covered under Materials, Page 42.

B) Contact Arrangement:

The insulation piercing teeth were arranged in an alternate pattern along the inside faces of the wedge shaped connector body cavity. This permitted the .050 spacing of the .025 wide conductors without violating the .060 minimum creep path requirement.

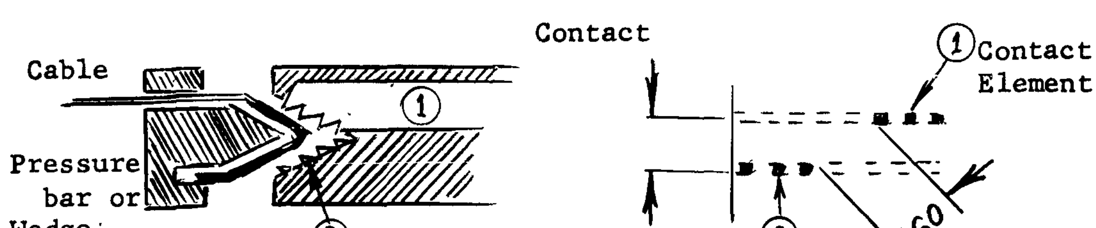


Figure 10

C) Contact Design:

In order to improve the reliability of the mated connector, it was felt necessary to change from the Hermaphoradic tabs

originally proposed to the proven pin and socket type contact. This also permitted a direct connection with the UPC connector and eliminated the need for the pressurized adaptor.

The female connector body or receptacle contains the male pins (opposite end of the insulation piercing elements). These pins are protected from damage by the connector body shell. This shell also provides polarization and alignment with the male connector body. The latter functions will be described later in this report. The contacts are assembled into the connector body and bonded into place. This bonding is necessary to protect the connector against environmental conditions when terminated to Flat Flexible Cable, but not mated to its connector half.

The male connector body or plug is designed to mate with the female connector body and with the Ultra-Miniature Printed Circuit Board Connector, SCL 6250.

When used to splice cable to cable, the plug is inserted into the receptacle, and is aligned by the receptacle shell.

When used to connect cable to the Ultra-Miniature Circuit Board Connector, the plug provides the guidance and alignment of the printed circuit board connector thru the cored guide holes designed into it. In this manner, the versatility of this connector is further increased.

The contacts which are assembled in the plug connector half are similar to those used in the receptacle half of the connector except that the insulation piercing contact has on its opposite end a female contact rather than a pin. This female contact is designed to accommodate both the printed circuit board and receptacle contact pins. These pins are assembled into the contact body. The molded plastic plug is then bonded onto the contact body thus providing closed entry of the contacts. Closed entry is desirable for a high reliability connector of this type. It eliminates probe damage to the contact fingers by preventing a pin or probe from being inserted behind the contact fingers, thus damaging them (see Figure 11).

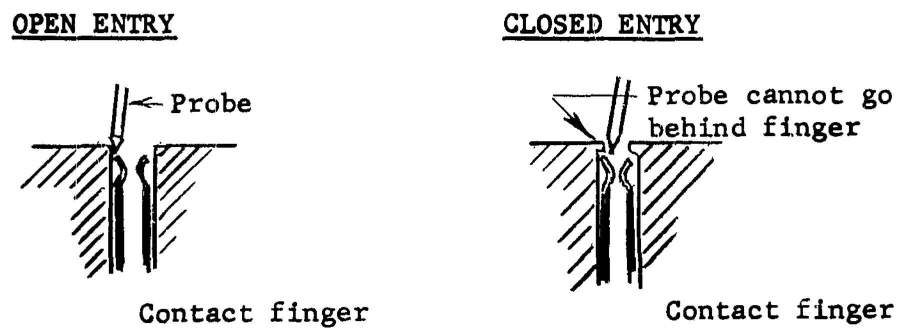


Figure 11

With this modification, BURNDY has found that the Ultra-Miniature Printed Circuit Connector pin is too short. This aspect was discussed during the July 21, 1961 meeting with the Signal Corps. It was decided that in order to maintain the advantages of the closed entry the 1/16" minimum engagement requirement would be eliminated.

D) Bonding in Contacts:

With the present design of the contact bodies, the contacts will be bonded in rather than being molded in. In molding in the contacts, it was expected that a flash problem would exist because of the clearance between the die cavity and the contact insert. This condition would permit the flow of plastic on and around the insulation piercing elements, thus making them ineffective for their specific use. Because these contacts are plated, the removal of this flash would undoubtedly cause damage to the plating and the edges of the teeth.

Another factor which eliminated the insert method was the impracticability of molding in insulation piercing elements and female contacts as a one-piece design. It would be necessary to develop a two-piece contact in spite of the lower reliability characteristics of this type of contact.

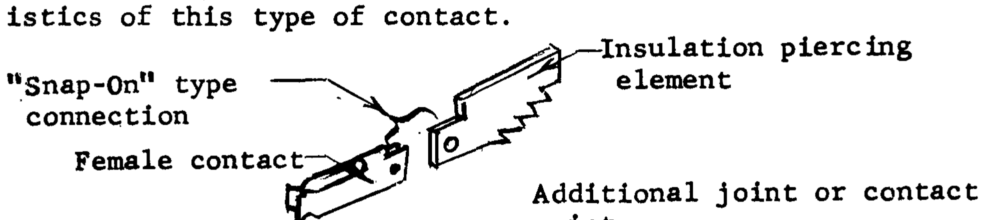


Figure 12

It was, therefore, decided to use the one-piece contact design and bond them in place.

E) Cable Alignment:

Alignment of the cable conductors with the insulation piercing elements is automatic within the connector. This is accomplished through the use of guide chamfers (see sketch).

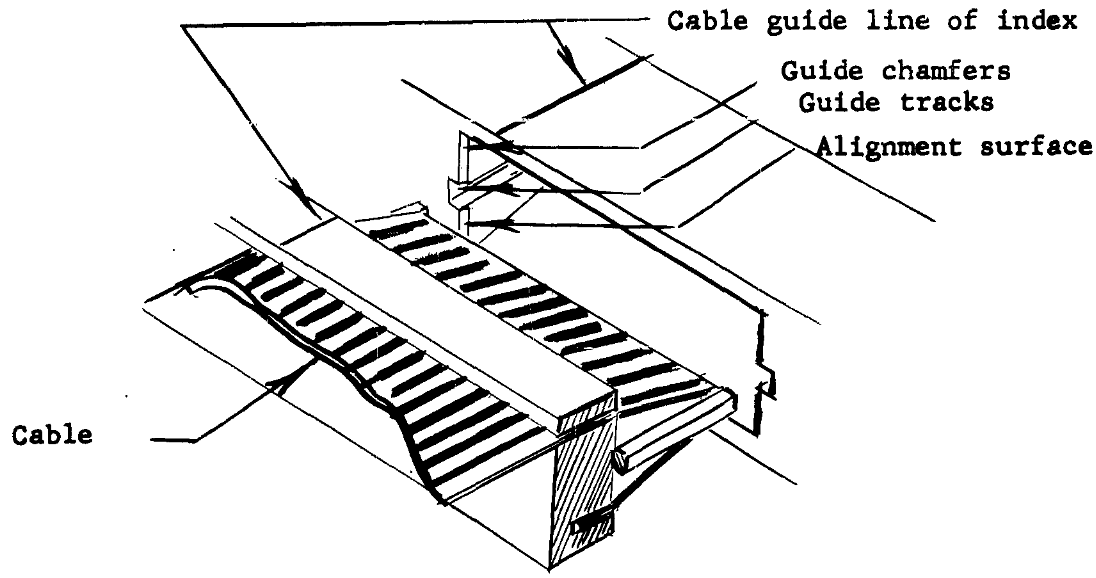


Figure 13

After the Flat Flexible Cable is placed on the wedge and the wedge is inserted into the connector body, the cable if not perfectly aligned will come in contact first with the guide chamfers. The function of these guide chamfers is to bring the cable in line with the alignment surfaces which are designed to align the cable with the insulation piercing contact elements. Before the cable reaches the insulation piercing elements, it must contact the alignment surfaces. Thus, the cable is always properly aligned with the insulation piercing elements.

There is, however, one area where the human error factor exists. Having a cable with 17 conductors, which conductor is #1, #2, #3, etc.? To provide for a reference the cable manufacturers have provided a molded-in colored thread which is used as a guide for indexing the conductors to the connector. A "guide line" (see Fig. 13)

is provided on the connector, as is done on the cable, in the form of a colored stripe on the connector body. The user must reference the cable (or pressure bar) to the connector body with the proper orientation (see Fig. 14).

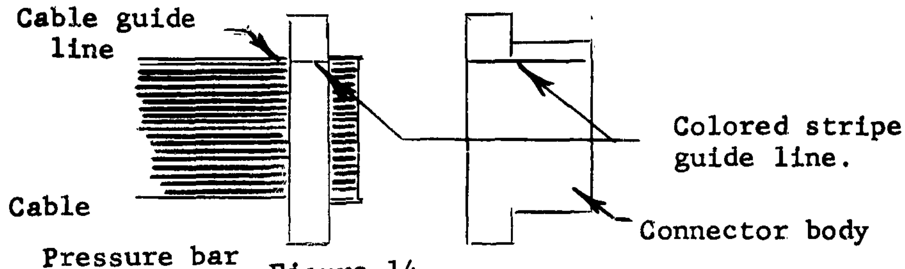


Figure 14

The cable may be installed onto the pressure bar in any manner, but the pressure bar must be oriented by the guide lines of both cable and connector to insure proper termination.

The process of cable installation on the pressure bar is as shown:

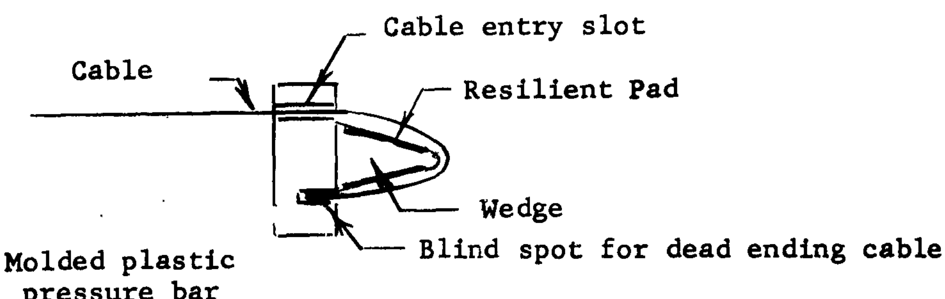


Figure 15

The cable is first threaded through the entry slot, guided around the wedge and the dead end of the cable is inserted into the blind slot. The pressure bar is then oriented by the guide line of the cable and connector body and inserted into the connector body by the use of screws.

Pressure bar guides and the guide tracks on the connector body (see Fig. 13) insure that the cable, if not properly indexed with the insulation piercing elements, will come in contact with the guide chamfers which will align the two.

F) Sealing Gaskets:

Three gaskets have been designed to meet the Signal Corps' sealing requirements. These gaskets are as follows:

#1 - Pressure Bar Gasket

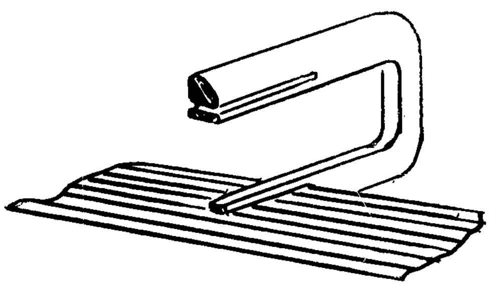


Figure 16

#2 - Contact Body Compression Gasket

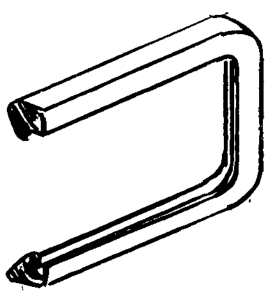


Figure 17

#3 - Interfacial Wiping Gasket

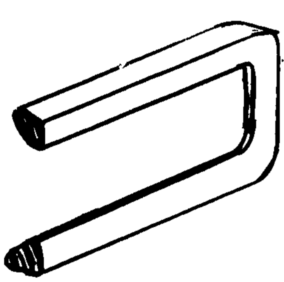


Figure 18

Assembly View

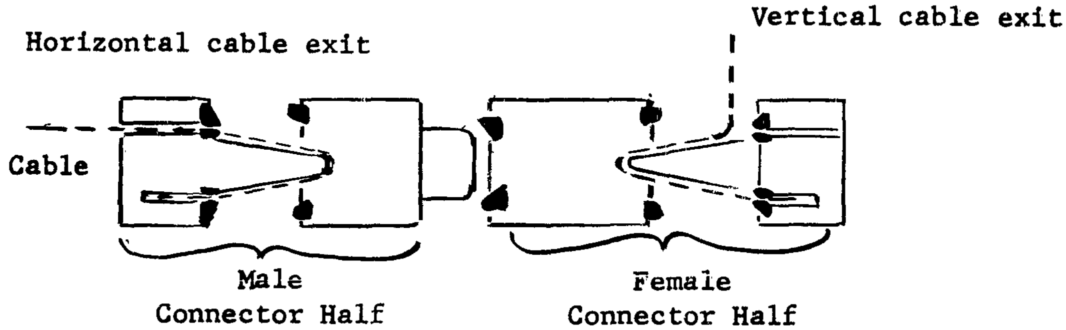


Figure 19

Gasket Cross Sections

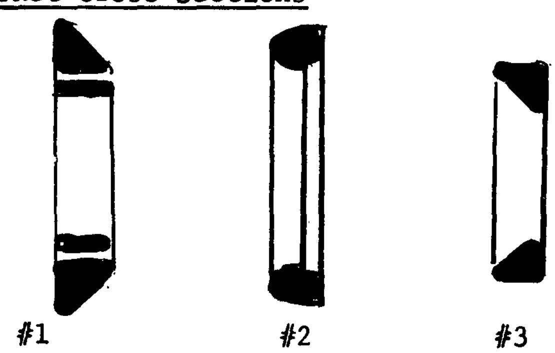


Figure 20

The functions of the Pressure Bar Gasket and the Contact Body Compression Gasket (#1 & #2) are two-fold. One, to seal the connector when the cable exits horizontally from the connector, and two, to seal the connector when the cable exits vertically from the connector (see Fig. 19). This can be shown by the following:

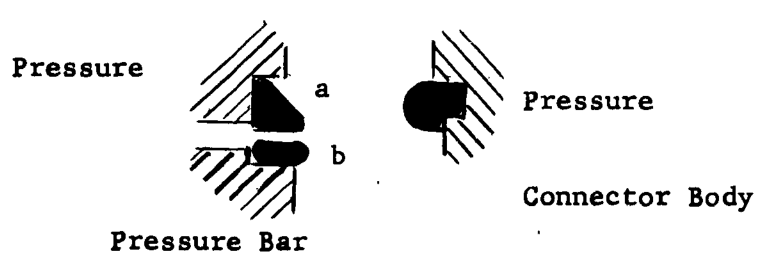


Figure 21

Horizontal Cable Exit Seal

Upon the application of pressure between gasket #1 and gasket #2, the cable is entrapped between sections (a) and (b) as shown on preceding page. As pressure increases between gaskets #1 and #2, the cable is sealed by the cantilever action of section (a) against section (b), as a result of the lateral force exerted by gasket #2. In this manner, the cable exit is sealed.

Vertical Cable Exit Seal (See Figure 19)

This seal is achieved by direct compression between gasket #1 and #2 with the cable entrapped between the two. Here again, although the horizontal exit slot is not in use, it is still necessary for it to be sealed. This is achieved in the same manner as described above.

Interfacial Wiping Gasket

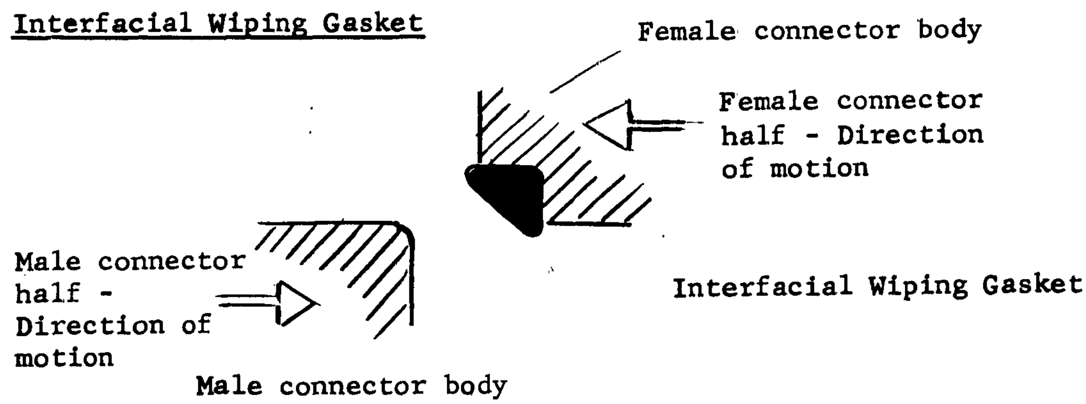


Figure 22

The function of this gasket is to seal the mating connector halves. Design specification requires this connector to be functional within a mating tolerance of ± 1/16". To maintain the sealing requirements with this mating tolerance this type gasket was chosen. This gasket functions on an interference principle. Since the internal dimensions of the gasket are smaller than the external dimensions of the male connector half (plug), the two have an interference fit. This causes the gasket to be compressed to allow the plug to pass through it. The compression which is exerted on the gasket acts against the plug and in this manner sealing is accomplished.

G) Material Investigation

The investigation of dielectric and resilient materials led to the following conclusions:

Dielectric Material --

The investigation of dielectric materials has resolved to consideration of two plastics. These are a polycarbonate resin (no additive) and a glass fiber polycarbonate (glass fiber additive). The trade name for these materials are LEXAN and CARBAFIL, respectively.

The properties of these materials are shown below:

PROPERTY	CARBAFIL G-50	LEXAN
Molding qualities	Good	Good
Injection molding temperature °F	550-700	550-600
Injection molding pressure, psi	10,000-30,000	15,000-20,000
Mold shrinkage, in/in	0.-0.002	0.005-0.007
Specific Gravity	1.4-1.52	1.2
Tensile strength, psi	18,000-20,000	8,500-9,500
Elongation, %	1.4-2.0	60-100
Modulus of elasticity in tension 10^5 psi	8-9	3.2
Compressive strength, psi	18,000-20,000	1,000
Flexural strength, psi	26,000-27,000	11,000-13,000
Impact strength ft.lb./in of notch (½X½ notched bar, Izod test)	3.0-5.0	2.8-3.0
Hardness, Rockwell	M95-E55	M70-R118
Thermal expansion, $10^{-5}/{}^\circ F$	0.7	3.9
Resistance to heat, °F (continuous)	275-300	275
Heat distortion temp., °F	300 (264 psi)	280-290
Water absorption, 24 hrs. 1/8" thick %	0.09-0.10	0.3
Burning rate	Self-extinguishing	Self-extinguishing
Effect of sunlight	None	Yellows slightly
Effect of weak acids	None	None
Effect of strong acids	Attacked slowly	Attacked slowly by Oxidizing acids
Effect of weak alkalies	None	Resistant
Effect of strong alkalies	Surface only	Attacked slowly

PROPERTY	CARBAFIL G-50	LEXAN
Effect of organic solvents	Soluble in aromatic and chlorinated hydrocarbons	Resistant to parafinic, soluble in aromatic and chlorinated hydrocarbons
Machining qualities	Good	Excellent
Deformation under load %		
4000 psi at 77°F	.1	.2
158°F	.1	.3
Dielectric constant		
60 cycles 23°C	3.8	3.17
10^6 cycles 23°C	3.7	2.96
Temp.-Low limit °F	-60	-100

Conclusions of Material Investigation

The comparison chart shows that the properties of CARBAFIL are better for this application than those of LEXAN.

In this specific application, the mold shrinkage property is one of the most critical. Because of the close tolerances necessary for indexing the conductors (cable) for a reliable connection, glass fiber polycarbonate (CARBAFIL) was selected. Although its lower temperature limit is -60°F against -100°F for LEXAN, further investigation proved that this was dependent on the configuration of the product and the internal stresses which it is subjected to. Further evaluation of CARBAFIL will be made after receipt of molded parts.

CARBAFIL has greater "creep resistance" than LEXAN. This also makes CARBAFIL more applicable because of the steady state loading that will exist in the TAPECON.

Resilient Materials

An investigation of resilient materials has also been conducted. The findings have been compiled for comparison of various properties:

PROPERTY	BUTYL (Isobutene) (Isoprene)	BUNA-N (Butadiene Acrylonitrile)	SILICON (Polysiloxane polymer)	NEOPRENE (Chloroprene)
Tear Resistance	Good	Fair	Fair	Good
Abrasion Resistance	Good-Fair	Good	Poor-Fair	Excellent
Aging Resistance				
Ozone	Excellent	Fair	Excellent	Excellent
Oxidation	Very Good	Poor-Good	Excellent	Excellent
Heat	Excellent	Very Good	Excellent	Very Good
Static(shelf life)	Excellent	Good	Excellent	Very Good
Compression set	Fair	Good	Good	Good
Oil & Gasoline Resistance	Poor	Excellent	Fair	Good
Acid Resistance	Excellent	Good	Fair	Good
Low Temperature Resistance	Good	Good	Excellent	Very Good
Heat Resistance	Fair	Good	Excellent	Very Good
Permeability to gases	Very Good	Fair	Fair	Good
Water Resistance	Very Good	Good	Good	Good

The mechanical requirements for the various type gaskets call for:

#1 Pressure Bar Compression Gasket -- compression
abrasion

#2 Connector Body Compression Gasket -- compression
abrasion

#3 Inter-facial Wiping Gasket -- abrasion
tear

#4 Pressure Bar Resilient Pad -- abrasion
tear
compression

Based on these requirements and the properties of the various materials, Chloroprene (trade name NEOPRENE) was initally selected, primarily for its resistance to tear and abrasion and also for its lower cost.

The first model connectors submitted for performance tests indicated compression set of the Neoprene pressure pads as a result of the temperature durability test. This problem was corrected by changing the pressure pad material and gasket material to Dow Corning 675U. The high temperature compression set characteristics of this material were vastly superior to any of the Neoprene rubbers we had tested. Though cementing of Silicone rubber is always a problem, we did find the Dow Corning 140 adhesive performed better than any of the other adhesives we tested.

PHASE IV: Procurement of Prototype Production Tooling

After the approval of the detail drawings by the Signal Corps single cavity molds were ordered for the fabrication of the EXPERIMENTAL and DEVELOPMENTAL MODELS required by the contract.

After a few unexpected delays due to mold building and molding difficulties, we received the first proof samples.

The molder had a little more difficulty than expected in filling the parts and avoiding distortion and warpage. There was also some difficulty in maintaining the bases of the slots on the same reference line.

PHASE V: Functional and Theoretical Evaluation of Components

I. Evaluation of Male and Female Contacts:

A) Prototype Production Stability:

Procedures for the evaluation of our contact elements located in the male and female connector half assemblies have been determined. The first evaluation will be performed on the female insulation piercing contact element (see Figure 22).

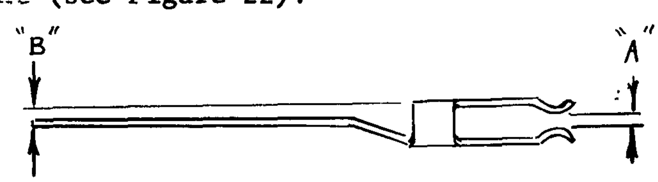


Figure 22

This evaluation was performed to determine the consistency of our prototype production methods. Since the blanking and forming operations are performed in the Norwalk facilities, close control was kept on the quality of the contacts produced. After the blanking and forming operations were performed on the contact fingers, the "A" dimension, shown in Figure 22 above, was measured and recorded with reference made to the contacts they are recorded from. These contacts were then heat-treated at 600^{o}F for two hours to bring them to a full hard condition. These contacts were then cleaned and the "A" dimension was measured to determine if any inconsistency from the initial measurement had been obtained due to heat-treating. This difference was negligable. The contacts were then plated.

The same evaluation was performed on dimension "B" shown in Figure 22, to determine if heat-treatment had any effect on the alignment of the insulation piercing element with the female contact portion. This was necessary because the insulation piercing portion of the contact element is bonded into the panel, and must provide alignment of the female contact portion with the closed entry hood (Fig.23).

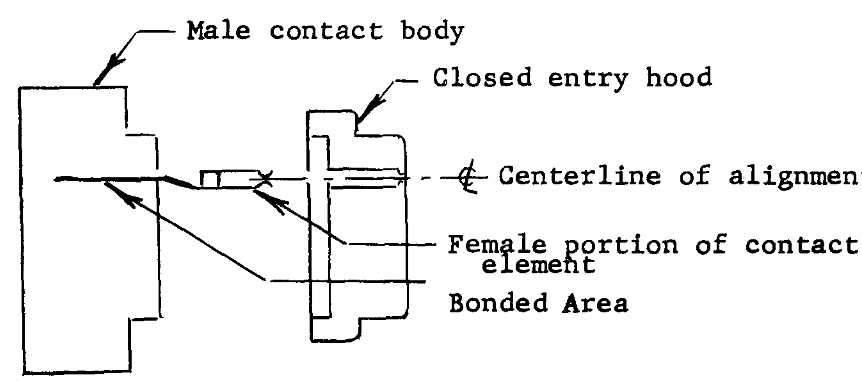


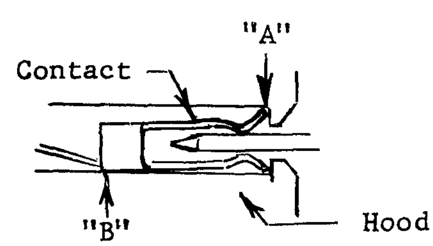
Figure 23

B) Insertion and Withdrawal Forces:

Insertion and withdrawal forces were then measured on these contacts. These contacts were first divided in two groups. In one group the contact fingers were adjusted to the minimum "A" dimension, and the other group, with the contact fingers, adjusted to the maximum "A" dimension. Engaging a male pin of maximum diameter with the female contacts having the minimum "A" dimension, insertion and withdrawal forces were recorded as well as the millivolt drop. The same procedure was followed engaging the minimum diameter male pin with the female contacts having the maximum "A" dimension. All readings were recorded for evaluation and analysis. It is important to note that each contact sample and its measurements were referenced to the results obtained from testing to determine the reasons for any discrepancies which had occurred.

There was little variation from the theoretical withdrawal values when the contacts were tested without the hoods in place. The values were considerably higher when tested with the hoods in place.

The millivolt drops were well within safe limits.



Slight interference between contacts and hood at points "A" and "B" caused withdrawal forces to be higher when tested with hoods.

Figure 24

II. Mathematical stress analysis of the female portion of the insulation piercing contact

A mathematical stress analysis of the female portion of the contact piercing element was made. This evaluation was made to determine the length of the female contact finger necessary for this specific application. The stress deflection characteristics were determined as follows:

Derivation

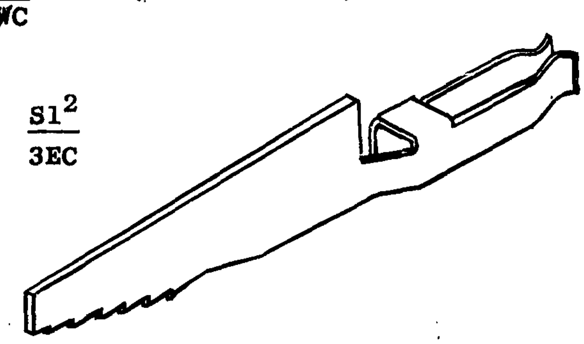
M - bending moment
l - beam length
W - load
S - material load stress
I - moment of inertia
D - deflection
C - distance from centroid to extreme fiber
E - modulus of elasticity

$$M = Wl = \frac{SI}{C}$$

$$\therefore l = \frac{SI}{WC}$$

$$D = \frac{Wl^3}{3EI} = \frac{\cancel{W}l^2}{3E\cancel{I}} \times \frac{S\cancel{I}}{\cancel{W}C} \qquad \text{(Substitution)}$$

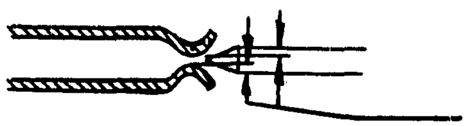
Deflection Equation $\quad \therefore D = \dfrac{Sl^2}{3EC}$



Material - Beryllium Copper
Thickness = .010 inch

Properties - Modulus of Elasticity = $E = 18 \times 10^6$ PSI
Yield Stress = $S = 150 \times 10^3$ PSI

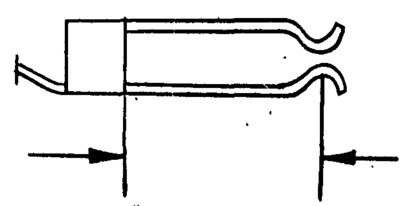
Optimum Engagement Between Pin and Socket -



interference and/or deflection.
optimum deflection = .007 inch = D
(based on nominal dimensions)

Under extreme tolerance conditions the deflection requirement is increased .005 inch which requires one female contact leg to withstand a deflection of .012 inch without setting.

To insure this deflection the length ("L") of the deflecting member must be determined



area where maximum stress occurs

point of pressure application by the pin entering the socket

$$D = \frac{SL^2}{3ec} \quad \text{or} \quad L^2 = \frac{D3ec}{S}$$

$$L^2 = \frac{.012\ (3)\ \ 18 \times 10^6\ (.005)}{150 \times 10^3}$$

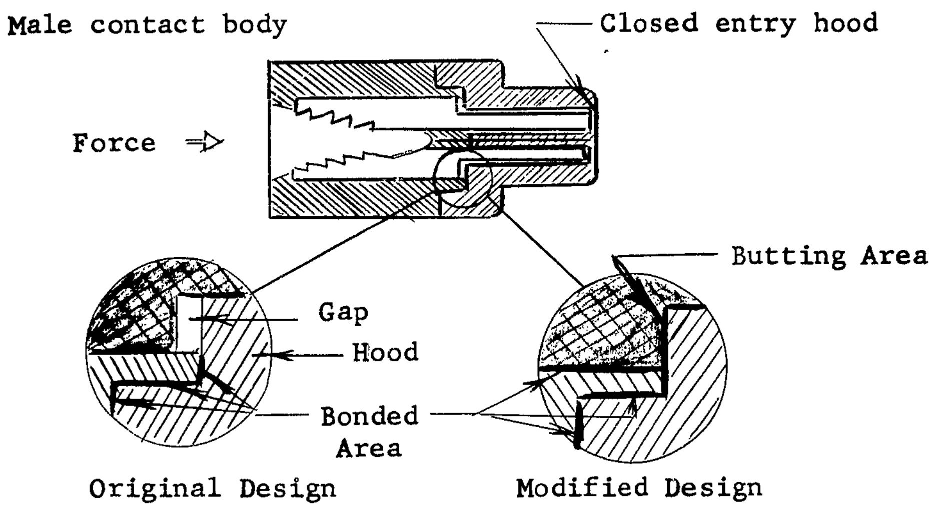
$$L^2 = .0216$$

$$L = .147 \text{ inch}$$

Due to tolerance variations on this dimension, it must be assumed that .147 inch represents the theoretical minimum length ("L") which can be allowed before the material will take a set. In the manufacture of this contact the dimension "L" is a resultant dimension which may vary as much as eight thousandths of an inch total, thus, the maximum length it may reach = .155 inch.

III. The Evaluation of Bonding Agents:

The quality and efficiency of bonded areas in this connector were evaluated. First, and of primary importance, the bonding of insulation piercing elements into their respective connector bodies. This bonding must accomplish a complete seal between the ends of the contacts, i.e., between insulation piercing and male and female portions. No problem was expected in the female connector half assembly which has male contacts bonded in it. However, in the male connector half assembly which contains the female contacts, a problem did exist. A slight modification of the hood was necessary. This change allowed the female contact to butt against the closed entry hood which is bonded to the connector plug assembly.



This change relieved the problem of bonding the contacts in place.

The same cement was found to work very satisfactorily on the Neoprene.

Later, when we changed to the Silicone rubber for the gaskets, we changed to Dow Corning 140 cement with the bonding primer being applied to the Lexan first.

PHASE VI: Testing of the Experimental Models

The experimental models were submitted for a series of tests to determine the level of functional compliance to the contract requirements.

It was concluded that BURNDY'S experimental models performed in accordance with the applicable requirements with the exception of the moisture sealing requirements. Some refinement of assembly procedure was considered necessary with regard to the potting and sealing processes. In addition, redesign and improvement of the gasket principle was required prior to the Qualification Testing of the development models.

The Signal Corps also reported a dielectric failure in one of the wedges. Their reports were reviewed and though it was concluded that we must have sent them a wedge which had been tested to failure, we ran a series of tests to determine if there was really any cause for concern.

The tests included testing samples of Flat Flexible Cable to destruction in close proximity with air, Lexan, Neoprene and Silicone rubber. (See page 50)

Though it can be seen from the following synopsis that there is no indication of a border-line condition in any of the tests, the wedge gasket was nevertheless changed to Silicone rubber which could only improve the breakdown characteristics.

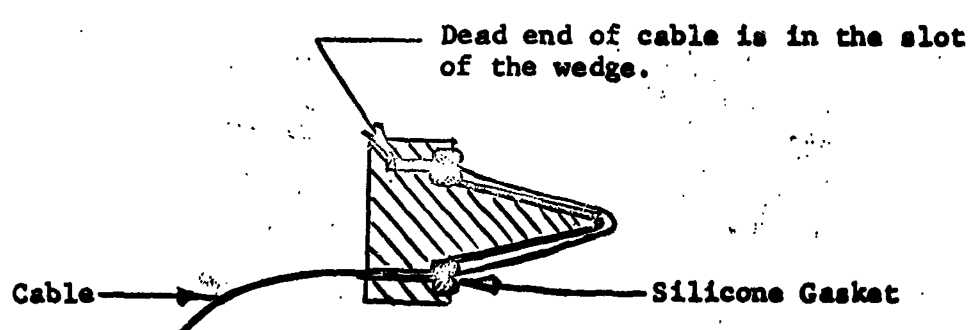
PHASE VII: Testing of Developmental Models

After the above mentioned improvements had been made, representative samples were submitted for tests to confirm the results of the corrective action.

TYPE "P" INSULATION .030/.050 CONDUCTORS
SPEC. 900V

	1 & 2	5 & 6	8 & 9	15 & 16
LEXAN	1750 (1)	2100 (1)	1800 (1)	1500 (1)
AIR	1750 (1)	2150 (1)	2000 (1)	2250 (1)
NEOPRENE	1750 (1)	3000 (2)	2250 (2)	2000 (1)
SILICONE RUBBER	4000 (2)	2000 (1)	3000 (2)	2200 (1)

Type (1) failure was across the end of the cut cable, while Type (2) failure was an interconductor breakdown between the layers of insulation. This only occurred where the end of the tape was effectively sealed by Silicone rubber or Neoprene held tightly in place. The Silicone rubber value shown in the table above is a reference value for the best possible condition, where the end of the cable is completely covered with the rubber, a situation not possible in the present design, as can be seen in the sketch below.



CONCLUSIONS

After careful evaluation of the various methods possible, the multiple element insulation skiving method was selected. The staggered tooth feature had to be dropped because it was not applicable to the mechanics of this connector design, i.e., it is necessary for the deepest penetrating teeth to be toward the dead end of the cable. The teeth on each contact, therefore, are on an angle parallel to the surface of the wedge and penetrate the insulation to equal depths.

In the early stages of the project, it was felt that the addition of more teeth would add to the reliability of the connector and by virtue of having more paths of current flow would lead to a more efficient connection. Though theoretically correct, the extra teeth required too much force to cause them to pierce the insulating material. This would have caused excessive bowing of the connector body and wedge or a substantial increase in the sections of these members. Also, the many small teeth did not allow sufficient clearance for the plastic insulation kicked up by the teeth. As a result, the teeth loaded up much as a fine file will on aluminum. Our final design, therefore, ended up with three teeth rather than seven teeth.

The research and testing done on the resilient backing for the cable was well warranted. There was a great deal of question as to whether a semi-rigid plastic wedge, a plastic or metal wedge with a rubber facing, or a rubber wedge with a molded in metal reinforcing element would provide the most effective back up. We found that .012 to .018 of Silicone rubber provided an excellent backing on a plastic wedge. The resilient backing effectively compensated for tolerance variations in tooth height, deflection of the wedge, gasket compression, etc.

The sealing of the wedge gasket around the tape and the sealing of the compression gasket against the wedge gasket seem adequate though possibly a little oversensitive to improper cementing techniques. The seal at the interface will leak if subjected to shock or vibration while under environmental conditioning. This might possibly be alleviated by increasing the compression on the wiping gasket, however, any increase in the compression will be drastically reflected in the engaging force.

The dielectric breakdown characteristics of the connector far exceed the capabilities of the cable. One possible problem area exists in that if a connector and cable assembly have been tested to dielectric failure (the failure will inevitably occur at the dead end of the cable) there will be carbon tracking down in the slot under the wedge gasket. This carbon tracking is hidden to the eye by the gasket. If a subsequent piece of cable is installed in the same wedge it too will break down, but at a much lower potential. I see no real cure for this except to discard any wedges which have been used to test for dielectric breakdown.

In mating this connector with the Ultra-Miniature Printed Circuit Connector, it must be kept in mind that the ± 1/16 engagement requirements cannot be met in this connector because of the closed entry features incorporated in the plug. This was discussed with the Signal Corps during the early stages of the development and deemed less essential than the closed entry feature. If the necessity ever occurs which requires this additional engagement tolerance, the pins on the UPC can be lengthened.

In order to comply with the Signal Corps' request of 15 November 1962, we made certain design changes to captivate the wedge screws. This was felt necessary to prevent the possible loss of the screws during assembly of the tape to the connector. We added threads to the wedge bushing and provided an undercut under the head of the wedge screws to permit them to turn freely once it is threaded into position.

This is a method frequently used to captivate such screws while at the same time permitting their replacement with a minimum of skill, tools, or effort.

To avoid the delay in making up all new wedges, the exsiting wedges were tapped for helicoils. Though this method is satisfactory for development models, the use of helicoils is unnecessarily expensive for production.

OVERALL CONCLUSION

The connector developed under this contract has become the forerunner of a new concept in Flat Flexible Cable termination. This new approach to cable termination will lead to many new uses for Flat Flexible Cable at a tremendous saving in weight, space and installation time. The development work and testing done on these connectors have proven beyond a doubt the feasibility of this design approach. As an outgrowth of the promise shown by this new approach an even smaller connector is now being developed.

RECOMMENDATIONS

Though the connector developed under this contract met the functional requirements set forth in the specifications, it did have the shortcomings of requiring too great a degree of skill and attention to detail during the assembly operation. Any deviation from the correct procedure can cause a potential failure in use. This characteristic is a fault of the mechanics of the connector design rather than one of principle.

It is, therefore, recommended that the work of developing a highly reliable production connector for Flat Flexible Cable be continued under a subsequent contract.

IDENTIFICATION OF PERSONNEL

NAME: Dr. W. F. Bonwitt
TITLE: Chief Engineer
BACKGROUND: Ph.D. Vienna, 1931
Lic., P.D. Connecticut, 1952
30 years' in connector design, testing and application

NAME: H. P. Dupre
TITLE: Assistant Chief Engineer
BACKGROUND: B.M.E., Stevens, 1941
20 years' of experience in connector design and application.

NAME: M. D. Lazar
TITLE: Connector Design Manager
BACKGROUND: Mechanical Engineering, the Cooper Union
17 years' experience in connector design and application.

NAME: G. M. Osborn
TITLE: Connector Design Engineering Supervisor
BACKGROUND: B.S.M.E., Renssalaer, 1958
11 years' mechanical design experience, including
6 years' in connector design.

NAME: E. Oshva
TITLE: Connector Design Engineer
BACKGROUND: B.S.M.E., C.C.N.Y, 1959
4 years' connector and tool design experience

NAME: H. Schenker
TITLE: Research and Test Engineer
BACKGROUND: B.S.M.E., Brooklyn Polytechnic, 1955.
M.I.E., N.Y.U., 1958
8 years' experience in connector design and testing

NAME: R. Knowles
TITLE: Connector Design Engineer
BACKGROUND: B.S.M.E., U.S. Merchant Marine Acad. 1951
2 years' quality control engineering
3 years' process engineering
4 years' connector design

NAME: L. Santoro
TITLE: Chief Draftsman
BACKGROUND: W.C.C.
12 years' experience in connector design.

AD ______________ ACCESSION NO. ______________

UNCLASSIFIED

BURNDY CORPORATION, NORWALK, CONNECTICUT

DESIGN OF FLAT FLEXIBLE CABLE CONNECTOR TO TERMINATE:

1. Flat Flexible Cable
   a. Rack and panel type.
   b. Plug and Receptacle type.

2. UPC Printed Circuit Board Connector
   (Ref. Dwg. ES-D-180571-2)

Final Report - 1 April 1961 to 18 February 1963
Signal Corps Contract No. DA-36-039 SC-87274
File No. 40596-PM-61-93-91
PR & C No. 61-ELP/D-4404-R
Technical Requirement No. SCL-7583
Unclassified

Prepared By: Robert Knowles

This report covers the complete contract from the first concept through the manufacture and testing of the development models.

Flat Flexible Cable Connectors

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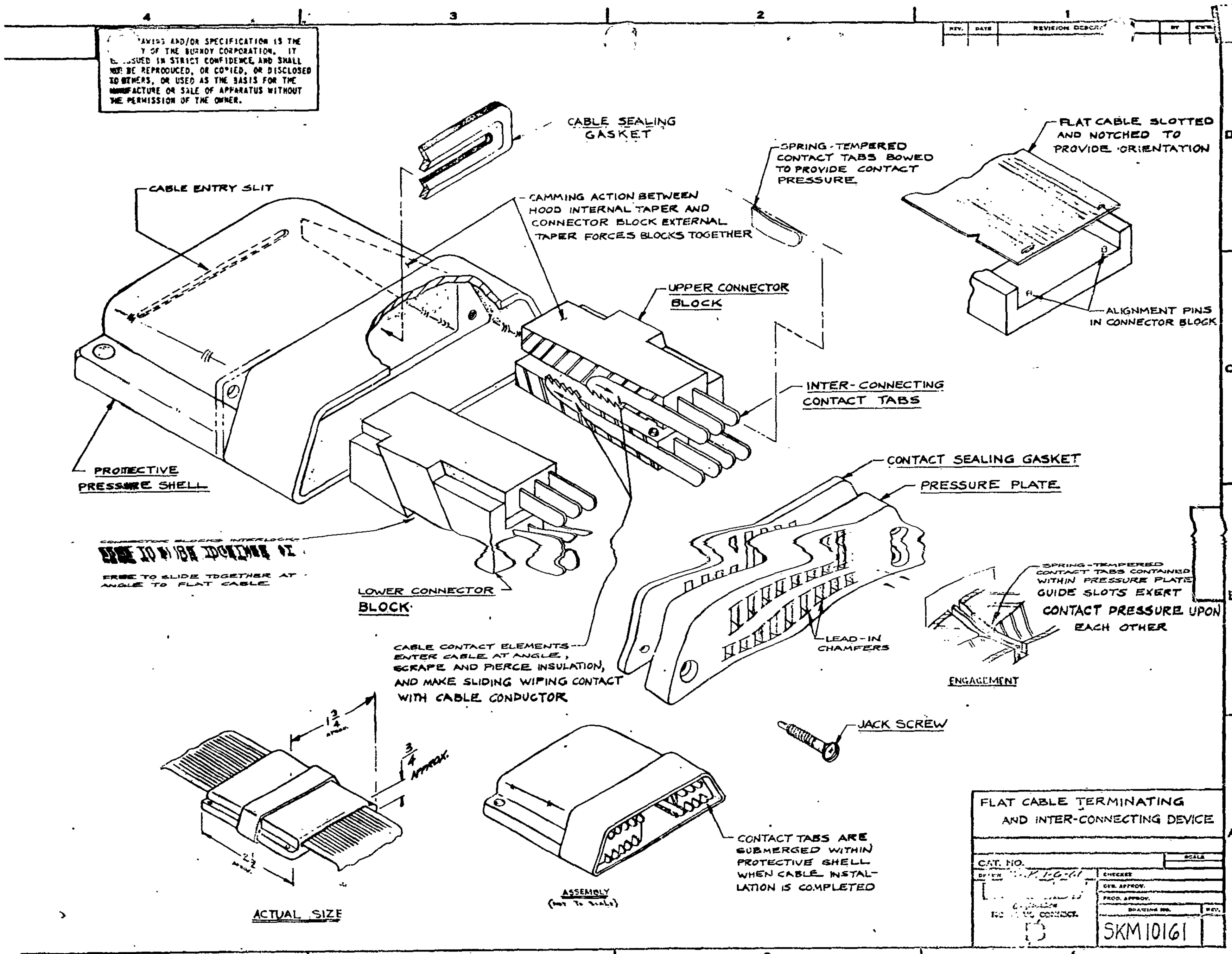
APPENDIX

REFERENCE DRAWINGS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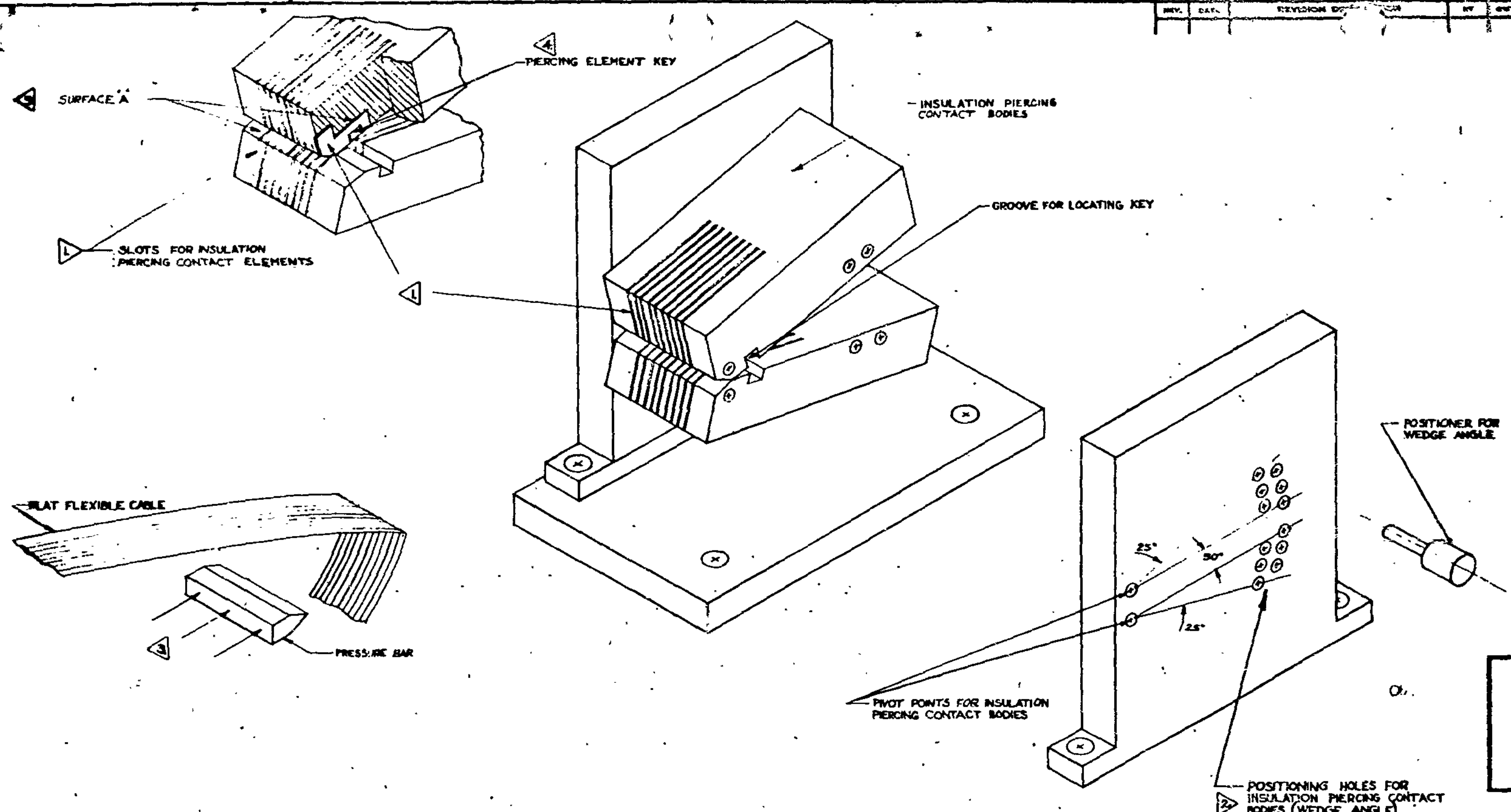
CABLE SEALING GASKET
CABLE ENTRY SLIT
CAMMING ACTION BETWEEN HOOD INTERNAL TAPER AND CONNECTOR BLOCK EXTERNAL TAPER FORCES BLOCKS TOGETHER
SPRING-TEMPERED CONTACT TABS BOWED TO PROVIDE CONTACT PRESSURE
FLAT CABLE SLOTTED AND NOTCHED TO PROVIDE ORIENTATION
ALIGNMENT PINS IN CONNECTOR BLOCK
UPPER CONNECTOR BLOCK
INTER-CONNECTING CONTACT TABS
PROTECTIVE PRESSURE SHELL
FREE TO SLIDE TOGETHER AT ANGLE TO FLAT CABLE
LOWER CONNECTOR BLOCK
CONTACT SEALING GASKET
PRESSURE PLATE
SPRING-TEMPERED CONTACT TABS CONTAINED WITHIN PRESSURE PLATE GUIDE SLOTS EXERT CONTACT PRESSURE UPON EACH OTHER
CABLE CONTACT ELEMENTS ENTER CABLE AT ANGLE, SCRAPE AND PIERCE INSULATION, AND MAKE SLIDING WIPING CONTACT WITH CABLE CONDUCTOR
LEAD-IN CHAMFERS
ENGAGEMENT
JACK SCREW
$1\frac{3}{4}$ APPROX.
$\frac{3}{4}$ APPROX.
$2\frac{1}{2}$ APPROX.
ACTUAL SIZE
ASSEMBLY (NOT TO SCALE)
CONTACT TABS ARE SUBMERGED WITHIN PROTECTIVE SHELL WHEN CABLE INSTALLATION IS COMPLETED
FLAT CABLE TERMINATING AND INTER-CONNECTING DEVICE
CAT. NO.
SKM10161



NOTES

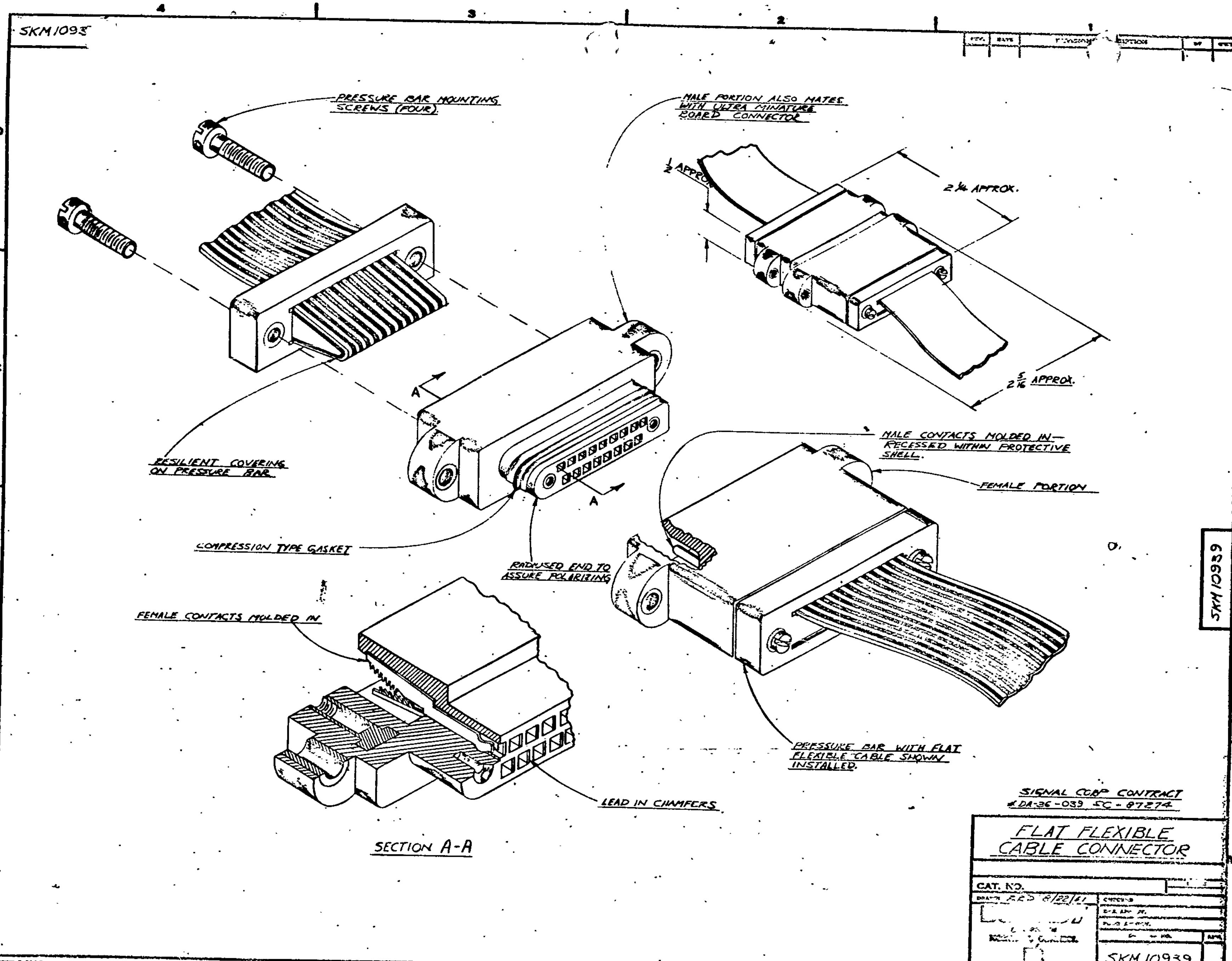
1. PIERCING CONTACT ELEMENT SLOTS ARE DESIGNED TO ACCEPT PIERCING CONTACT ELEMENT THICKNESSES OF:- .005, .008, .010, .012, .015, .020.
2. LOCATING HOLES ALLOW PRESSURE BAR ANGLES OF 25° TO 30° IN 5° INTERVALS.
3. FORCE ON PRESSURE BAR IS APPLIED AS SHOWN.
4. THE INSULATION PIERCING CONTACT ELEMENTS ARE SECURED BY A KEY AS SHOWN.
5. REFERENCE: PHASE I, PART 4, SECTION B, NO 3.

FLAT FLEXIBLE CABLE FIXTURE

CAT. NO.

SKM10826

D.D. 18320

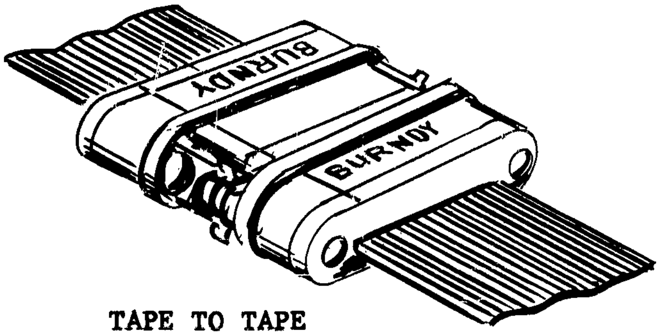


SIGNAL CORP CONTRACT
DA-36-039 SC-87274

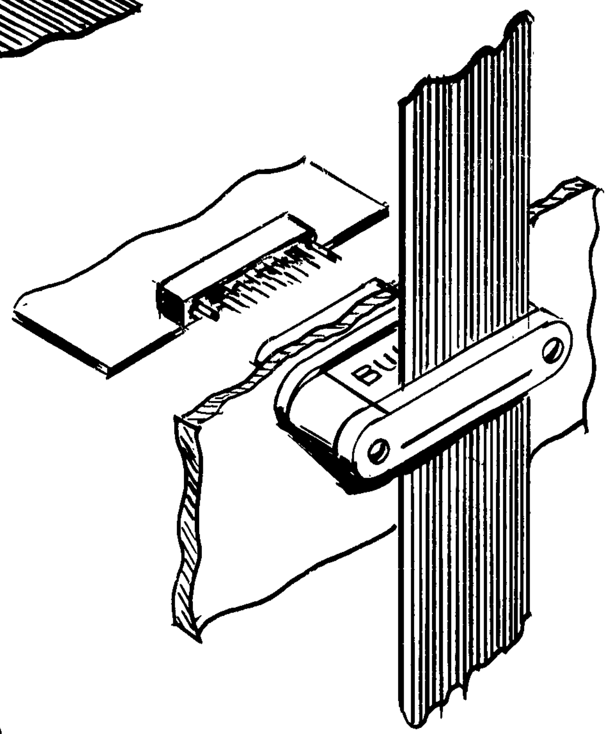
FLAT FLEXIBLE CABLE CONNECTOR

CAT. NO.

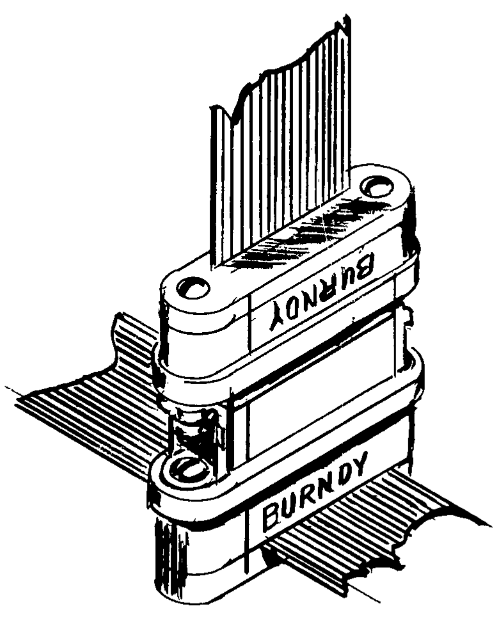
SKM 10939



TAPE TO TAPE

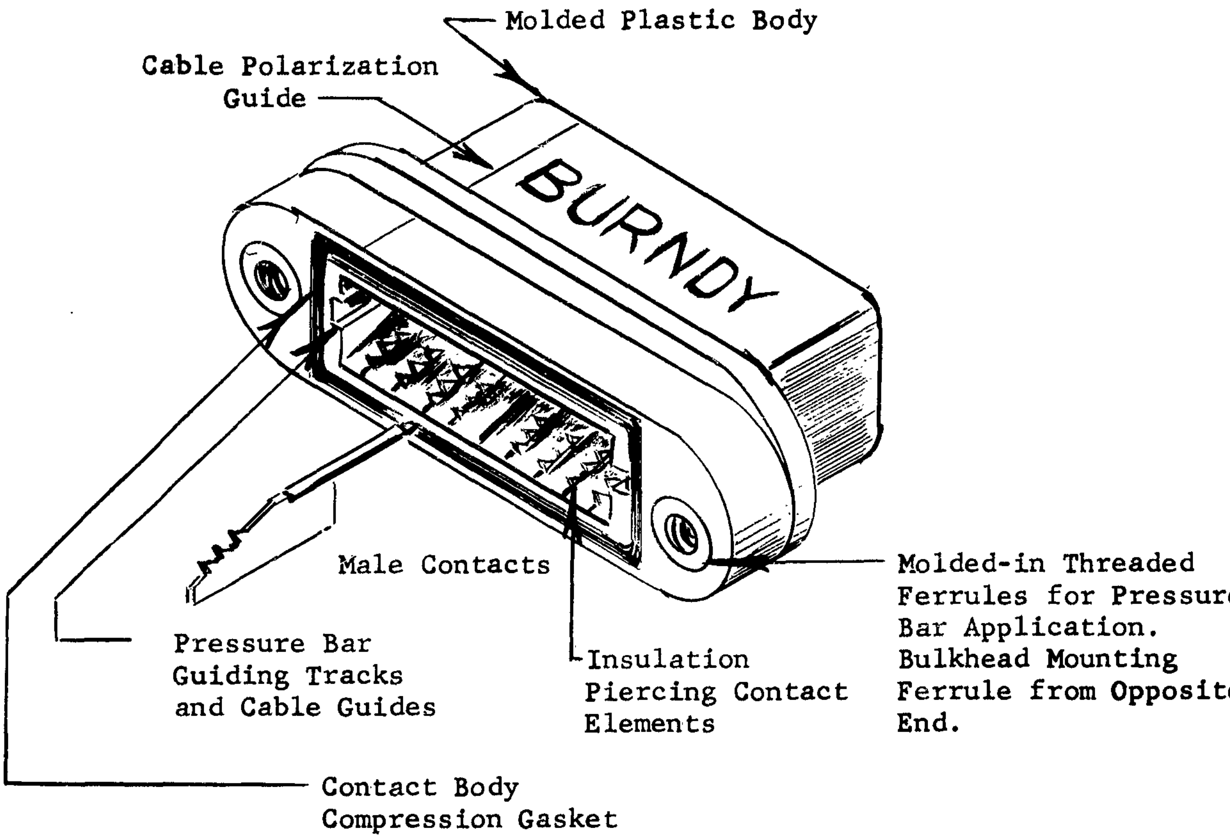


TAPE TO 'UPC'



TAPE TO TAPE
(SPAN TAP)

FEMALE CONNECTOR BODY - RECEPTACLE



MATERIAL

Connector body --- Glass filled polycarbonate

Bushings --------- Aluminum

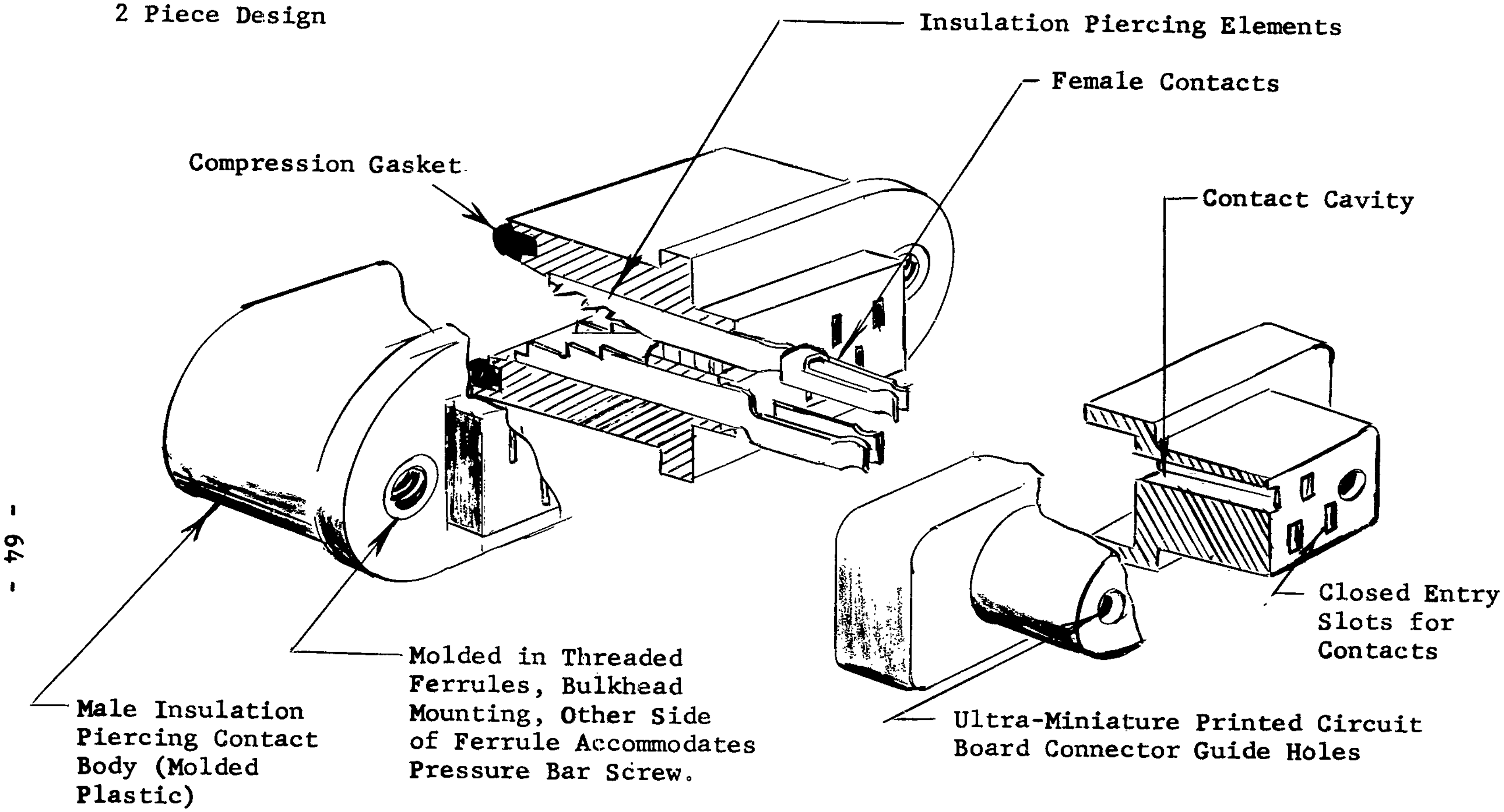
Gaskets ---------- Silicone Rubber (Dow Corning 675U)

Contacts --------- Beryllium Copper

Plating ---------- 110 microinch min. Hard Gold over 150 microinch Copper

MALE CONNECTOR BODY - PLUG

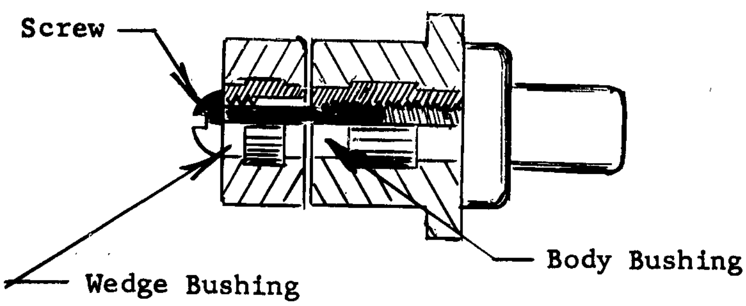
2 Piece Design



MATERIAL

Plating------- 110 microinch Hard Gold, 150 Microinch Copper
Hood---------- Glass filled polycarbonate
Body---------- Glass filled polycarbonate
Bushings------ Aluminum
Gaskets------- Silicone rubber (Dow Corning 675U)
Contacts ----- Beryllium Copper

CAPTIVATED SCREW



LATCHING DEVICE